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WEIGHING MACHINES.

BY WM. KENT, M.E.

[*A lecture delivered before the* FRANKLIN INSTITUTE, *February 10, 1888.*]

Mr. KENT was introduced by the Secretary of the INSTITUTE and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

I had the pleasure of hearing the lecture last Monday evening in this hall, and the lecturer said that it was customary to carry the subjects of lectures back to the book of Genesis and to Homer. My subject, I think, may be carried back to a still greater antiquity, for among the earliest questions asked by man of his fellow-man must have been "How much does it weigh?" And the answer would have been given after reference to the first weighing machine, which is man's

own hand, or his muscular strength. The first example of barter and sale may have included an offer like this from the seller: "For that piece of silver I will give you as much grain as you can lift from the ground, or for that smaller piece I will give as much as you can raise shoulder high." No doubt the weighing was done by the muscles of man before any more accurate machine was invented for the purpose.

A weighing machine is any machine or contrivance used to ascertain the heaviness of a body.

Scientifically speaking, *weight* is the result of the attraction of gravitation upon a body, and as the force of gravity is not the same at different parts of the earth's surface, so the weight of any piece or body, if by weight we mean the effect of gravity upon it, differs according to the place at which it is weighed. Thus the writers on natural philosophy tell us that a mass of iron which weighs 1,000 pounds at the Equator would weigh 1,005 pounds at the Pole; 500 pounds at a point 2,000 miles below the surface or 1,650 miles above it; 2,600 pounds on the surface of Jupiter, and 28,000 pounds on the surface of the sun.

But as ordinarily used, weight does not mean the absolute heaviness of a body or the effect of gravity upon it, but the relative heaviness; that is, its heaviness as compared with that of a certain piece of metal which is taken as a standard, and weighed at the same place and under the same conditions.

The accepted standard in English speaking countries is the pound avoirdupois, which is the weight of a certain piece of metal kept in the custody of the warden of the standards in London. The standard for France and for all countries which have adopted the French system of weights and measures is the kilogram, the weight of a certain piece of metal kept in a government office in Paris.

A weighing machine then is not, generally speaking, used to determine the force of gravity upon a body, but to determine what is its heaviness as compared with that of certain pieces of metal which are assumed to be standards.

For the comparison of standard weights with each other,

for governmental and scientific purposes, instruments of the utmost possible refinement are required, so as to make the error of ascertainment of their relative weights as small as possible. For commercial purposes such refinement is not attempted, but it is desirable that the error of weighing be so small that it can create no dissatisfaction in the mind of either buyer or seller, or user of the weights for any purpose. Thus in weighing tea or sugar in a grocery store, an error in weighing would be allowable if it was not large enough to cheat either buyer or seller by the amount of one cent in the calculation of the total price of the article weighed. In a drug store, the prescription balance should be so accurate that the largest possible error that could be made in weighing the strongest poison known to the Pharmacopœia could not produce the effect of an overdose and endanger the life of a patient. In chemical analysis, the largest allowable error must be less than the limit of accuracy of the process used by the chemist, or say $\frac{1}{1000}$ of one per cent. So the refinement or accuracy necessary in a weighing machine depends chiefly upon the purpose for which the weighing is done.

The mechanical principles upon which weighing machines are based are quite various, but in general they all have one idea in common, that of opposing to the force of gravitation, which acts upon the body to be weighed, some resistance the amount of which can be determined and expressed in units of the accepted standard. I will now enumerate the several mechanical principles which have been adopted or proposed for weighing machines, and show some examples of their application.

(1) *The elasticity of metals or other substances.*

Probably the simplest illustration of this principle is seen in this cheap weighing machine (*Fig. 1*), consisting of a flexible steel strip *A*, rigidly fastened at one end to a firm pedestal *B*, and carrying at its outer end a pan *C*. A one-pound weight placed in the pan *C* will bring the pointer down to the mark *1* on the graduated standard, two pounds brings it down to the mark *2*, and so on. By finely graduating the index plate and by reading carefully the

position of the pointer upon it after it ceases vibrating, a fairly accurate weighing machine for a limited range of purposes is obtained.

Weighing on this crude machine is done by the method known as "weighing by substitution," which consists in substituting, for the substance on the scale pan whose weight is to be determined, standard weights sufficient to produce exactly the same effect upon the scale. The sum of the standard weights so used is the weight of the substance. For example, suppose we put on the scale pan of this machine a piece of metal of unknown weight, it depresses the pointer to a spot on the graduated plate, which spot we mark with great exactness. We now carefully remove the piece of metal and substitute standard weights sufficient to

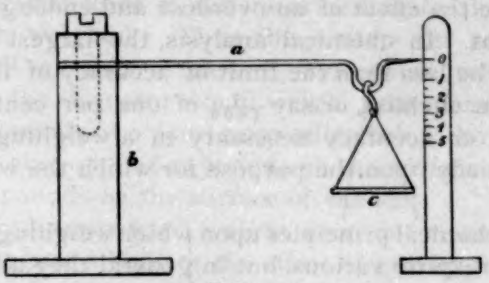


FIG. 1.

bring the pointer to exactly the same position. If it requires just one pound, one ounce and one-eighth of an ounce to bring the pointer to the marked spot, then that is the weight of the piece of metal. This method of substitution is employed in the very finest weighing for scientific purposes, because it enables us to avoid many of the errors common to the ordinary methods of balancing a weight on one side of a scale beam against a weight on the other.

Another form of machine, using the flexibility of this same metal strip, might be made by fastening or supporting the strip at each end on a separate pedestal, and noting the deflection of the middle point. A railroad bridge might thus be used as a weighing machine to weigh the trains of cars that cross it, the heavier the train, the greater of course being the deflection.

The most common illustration of the use of the principle of the elasticity of metals is seen in the ordinary spring balance, which consists simply of a spirally wound wire, which is held at one end and the weight to be weighed suspended from a hook at the other. These wire coils may be used either in compression, like the coiled spring of a street car, or in extension, like the ordinary spring balance. (Specimen shown by the lecturer.) The common form of balance, with a pointer rotating on a dial, is just the same, with the addition of a small rack and pinion to give the rotary motion.

Instead of the elasticity of metal, we may use that of other substances, such as cork, or India-rubber, or we may use the elasticity of air. Suppose a cabinet organ bellows, or a blacksmiths' bellows, perfectly free from leaks, and well inflated with air. Place a pound weight on the upper plate of the bellows, and it will be depressed slightly. Two pounds will depress it twice as much, or nearly so. Thus an index scale of depressions corresponding to certain weights might be constructed, and the bellows thus become a weighing machine. The common gas-holder of the gas works may be used as a weighing machine. It consists of an inner tank inverted in an outside tank, which is filled with water. Gas is introduced into the inner tank, raising it to a certain height. Weights are now placed on the top of the inner tank, depressing it in proportion to the amount of weight. The amount of the depression, recording the pressure to which the contained gas is subjected, is also a record of the weight applied, and thus the gas-holder becomes a weighing machine.

(2) *The buoyancy of liquids.*

I have one illustration of this principle here, in the common hydrometer, used for determining the density of liquids, *Fig. 2.* It may also be used to determine the weight of small bodies. I have it here balanced in strong brine, and a little pan on top of the stem, in which I place this ten-grain weight. It depresses the stem a considerable distance, so that within a range of from one-tenth grain to twenty or thirty grains this hydrometer makes a fair weighing machine.

On the same principle a boat or any vessel floating in water may be used as a weighing machine. When the vessel is unloaded, the water line is at a certain mark. As the vessel is loaded, it sinks deeper and deeper in the water, and successive marks showing the amount of water the vessel is drawing, also measure the weight of the cargo placed on board.

(*3*) *The chain balance.*

What is called the chain balance is described in the books, but I am not aware that it is ever used in practice.

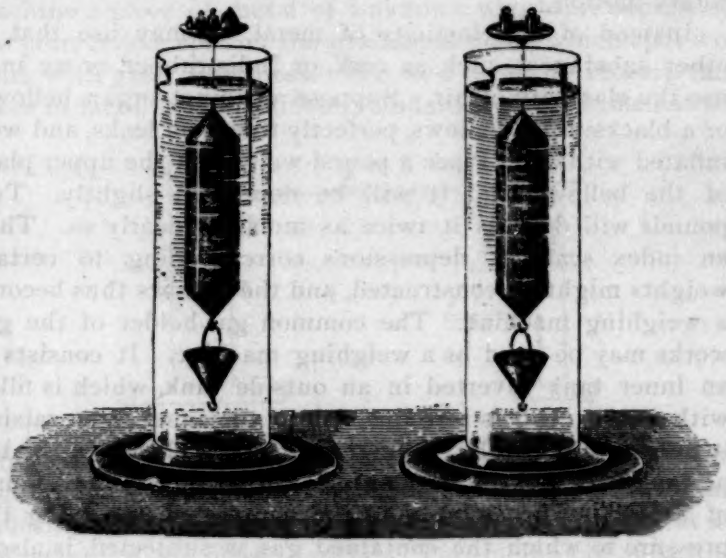


FIG. 2.

I have here a rough model of one, which is chiefly interesting to show how a crude weighing machine might be made if no better one was at hand. It consists simply of two upright posts (*c d*, *Fig. 3*), between which is loosely stretched a cord or chain, *a b*. To two points in this chain are attached the scale pans, *e f*. When the scale pans are unloaded, the chain will take a definite position, depending upon the position of the points of attachment of the scale pans. If one pan is loaded, that pan will take a lower position, while the other one will rise, the angles between the ends of the chain and the posts changing accordingly. If

an equal load be placed in the other pan, the chain will return to its original position.

(*4*) *The pendulum or bent-lever balance.*

This is a balance which has had rather limited application hitherto, the most commonly-known form being a cheap and not very accurate letter balance, for weighing a few ounces.

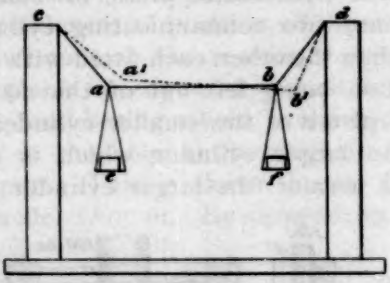


FIG. 3.

I have here a rough model, *Fig. 4*, illustrating the principle, and also a rather complicated modification, a housekeeper's cheap scale, weighing up to ten pounds. It consists, in its simplest form, as the model shows, of a bent arm *a*, pivoted near one end to an upright support, and carrying at the end of the vertical portion a weight *c*, and at the end of the

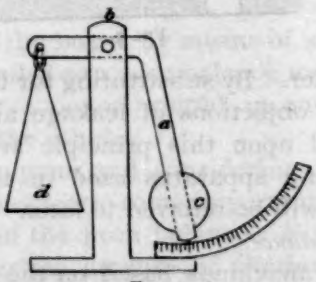


FIG. 4.

horizontal portion the scale pan *d*, suspended from a pivot. It is evident that as weights are placed in the scale pan, the weight *c* will be caused to move outwards from the supporting pillar, until the leverage of the arm and weight on one side of the pillar counterbalances the effect of the weight in the scale pan. The balance may be standardized by

marking on the graduated index the position at which the arm comes to rest under the application of successive weights.

(*5*) *The hydrostatic balance.*

The most elementary form of this balance is shown in the sketch on the blackboard (*Fig 5*). It is based on the principle of the hydrostatic press, or common hydraulic jack. There are two communicating cylinders, one very much larger than the other, each fitted with a piston. Leakage and friction being left out of the account, a weight placed on the piston of the smaller cylinder will balance a weight on the larger cylinder, which is as many times greater as the area of the larger cylinder is greater than

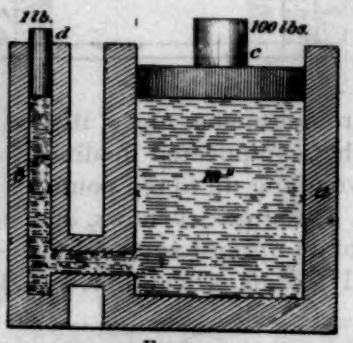


FIG. 5.

that of the smaller. By substituting for the pistons flexible diaphragms, the objections of leakage and piston friction are avoided, and upon this principle are constructed the hydraulic-weighing apparatus used in the Emery testing machine, which will be referred to later.

(*6*) *The even balance.*

The weighing machines based on the principles already referred to are of quite restricted application. We now come to the simplest, most ancient, and most universally used form of weighing machine, the even balance. I have here the rudely constructed parts of a model, consisting of two pieces of board, three feet long and five inches wide, a supporting pillar and two upright pan supports, and two pans with strings for suspending them, also a number of

different kinds of pivots, with which I will construct several rough models illustrating the even balance in many of the forms it assumes in use. No doubt the earliest form of the even balance was the "see-saw," used by children in their play, a plank placed across a log, and a child on each end balancing one another. As an accurate weighing machine, however, the "see-saw" is not a success, on account of the friction and variableness of position of the middle bearing. The first improvement on the see-saw was probably made by turning the plank up edgewise to give it greater resistance to bending, and boring a hole in the middle of it, and inserting a pin in the hole, supporting the pin also on a bifurcated support. This is shown in the form now presented in the model (*Fig. 6*). By suspending the scale pans

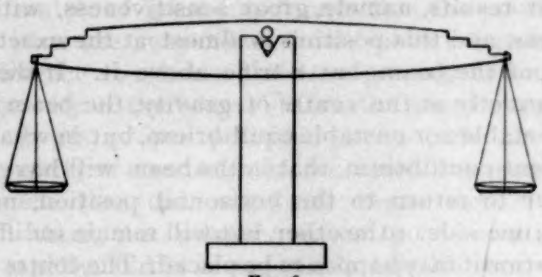


FIG. 6.

from the ends of the board by means of strings, we have a fairly good suspended-pan even-balance weighing machine. You observe that a pound weight in one pan balances a pound weight in the other.

Removing the pans, and considering the action of the beam itself, we may learn some important facts concerning the construction of the even balance. First we notice that the pin has a certain amount of friction in its bearings, which brings the beam to rest after two or three oscillations, and prevents its being set in motion except by the addition of quite an appreciable weight on one side or the other. This is very objectionable in a weighing machine, and teaches us that a perfect balance should have a frictionless pivot. Let us make the pivot of polished steel, of small diameter, so as greatly to reduce the friction, and we dis-

cover another peculiar feature of the even balance. If the pin is placed in the uppermost of the three holes the beam oscillates rapidly. When brought to rest a half-ounce weight placed on the end of the beam moves the beam out of its normal or horizontal position to a slight degree only. Place the pin in the lowest of the three holes, and the beam will not remain in the horizontal position at all, but will fall to one side or the other, showing a tendency to turn upside down, so as to bring the supporting pin in the upper edge of the beam as before. This is the condition of unstable equilibrium, or top-heaviness, while in the first test, in which the supporting pin is in the uppermost hole, the condition is one of stable equilibrium. By such tests we learn that there is a position of the supporting pivot which will give the best results, namely, great sensitiveness, without top-heaviness, and this position is almost at the exact centre of gravity of the beam, but a trifle above it. If the pivot be placed exactly at the centre of gravity, the beam will be in neither stable nor unstable equilibrium, but in what is called indifferent equilibrium, that is the beam will have neither a tendency to return to the horizontal position, nor to fall towards one side or the other, but will remain indifferently in any position it may happen to be placed. The centre of gravity must be just a little below the centre of support, so that as the centre of gravity always tends to take a position in a vertical line below the point of support, the beam will always tend to return to the horizontal. Placing the pin in the middle one of the three holes we notice that the beam oscillates very slowly, but always comes to rest in a horizontal position. A half-ounce weight placed on one end of the beam now deflects the beam to a much greater extent than when the pin was in the upper hole.

The round pin, however, is still objectionable as a pivot on account of its friction, which cannot be got rid of, as well as for other reasons of which time will not permit me to speak. Suffice it to say that the round pivot has been replaced by the knife edge in nearly all balances which have been used during the past 2,000 years at least. The balances used in ancient Rome, according to pictures which have come

down to us, show the use of the knife edge, and I have no doubt the balances shown in the sculptured pictures of the Egyptian pyramids also had knife edges. (The lecturer here showed on the screen a picture of an Egyptian balance, and also the picture showing the ceremony of weighing the Great Mogul of Tartary.)

Instead of suspending the scale pans by means of strings tied to the ends of the beam, as I have them in the model, it is usual to have knife edges firmly set into the ends of the beams, to which the pan supports are attached by means of swinging links. By means of the three strings which are attached to each end of the model beam, each passing through a hole and secured by a knot resting on one of the little steps at the end of the beam, we can show that it is a matter of great importance that the points from which the pans are suspended should have a certain position in reference to a horizontal line passing through the centre of gravity of the beam. With the pivot supporting the beam in its proper position, just a trifle above the centre of gravity of the beam, if we attach the pans to the strings attached to the outer and lower step, and put weights in them, the balance ceases to be sensitive. It oscillates rapidly, and is in too stable equilibrium. If we tie the pan supports to the innermost strings, which are suspended by the knot on the uppermost step, the balance again becomes top-heavy, or in unstable equilibrium. If we attach the pan supports to the middle string, supported by the knot on the middle step, the balance oscillates slowly, no matter whether lightly or heavily loaded, it is quite sensitive to small additions of weight to either pan, and it always returns to the horizontal position. Hence we learn that the end pivots of a suspended-pan balance of this general class, that is with round or knife-edge pivots, should always be on a horizontal line with the middle pivot, that is the edges of the three knife edges should be in the same plane.

I have here a very fine scale beam, with three knife edges, made by Mr. Troemner, of Philadelphia, from which may be learned the accuracy of workmanship necessary to

make a good knife-edge balance. The end pivots must be exactly equidistant from the centre pivot, the edges of the three pivots must lie in the same plane, the edges of each pivot must be exactly at right angles to the beam, both horizontally and vertically, which condition also assumes another essential requirement, that the edges must be parallel with each other. Those of my audience who are expert machinists will recognize the fact that to produce absolute exactness in all these conditions is a practical impossibility, and that to produce sufficient exactness to meet the requirements of a fine weighing machine is one of the most difficult tasks that can be performed by a mechanic. I have a number of knife-edge balances here, kindly loaned for this lecture by Messrs. Riehlé Brothers, of this city, which show various modifications of construction.

(7) *The lever or steelyard balance.*

The even balance has one serious objection as a weighing machine for heavy weights, viz: the necessity of placing weights in one pan of the balance equal to the weight of the substance which is being weighed in the other. For weights up to ten or twenty pounds, this is no great inconvenience, but when we wish to weigh hundreds or thousands of pounds it becomes intolerable. This led to the adoption in very early times of the lever balance or, as it is sometimes called, the Roman steelyard. The picture shown on the screen of an ancient Roman balance bears very close resemblance to the steelyards used at the present day. The principle upon which this balance is based is that of the lever, namely, that a heavy weight suspended from the end of the short arm of the lever may be balanced by a smaller weight suspended from the end of the long arm, the weights being inversely proportional to the lengths of the arms, or the product of the heavier weight multiplied by the length of the short arm being equal to the product of the lighter weight multiplied by the length of the long arm. This may be illustrated by the model. If we place the supporting pivot in one of the holes near one end of the beam, so that the distance of the pin from one pan support is three times its distance from the other pan support, and add enough

weight in the pan on the short arm to balance the beam, then place three pounds in the pan on the short arm and it will be exactly balanced by one pound placed in the other pan (*Fig. 7*).

In practice the steelyard balance does not generally have a pan support, or weight holder attached to each end of the

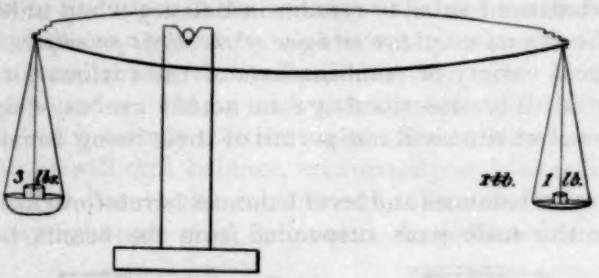


FIG. 7.

balance, but only to the short end, while on the long arm there is a movable weight, which may be placed at any position required to balance the weight suspended from the short arm. This is shown in the ancient Roman picture. Marks and nicks are placed upon the beam to indicate the positions at which the movable weight should be placed to

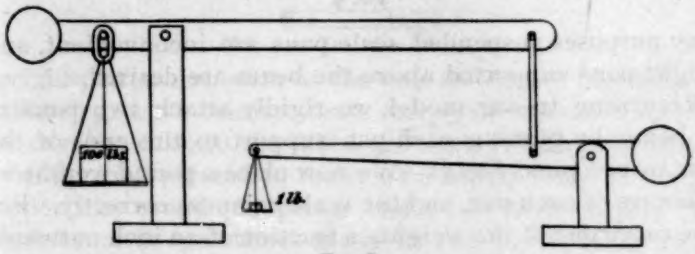


FIG. 8.

counterbalance certain definite weights suspended from the short arm.

(*8*) *The compound lever balance.*

This is merely an extension of the principle of the steelyard, by using two or more steelyards linked together as shown in the sketch (*Fig. 8*). If a weight of 100 pounds is suspended from the short arm of a beam, whose arms are to each other as 10 to 1, a force of ten pounds applied at the

end of the long arm will balance it, but this force may be applied by means of a second lever. If this second lever also has a ratio of length of arms of 10 to 1, one pound applied at the end of the long arm of the second lever will balance 100 pounds at the short end of the first lever, the weights of the levers themselves of course being first counterbalanced so as to remain in balance when unloaded.

(9) *Combinations of two or more of the eight principles.*

A great variety of combinations of the various forms of balance already described are in actual use as weighing machines, but time will not permit of their being considered in detail.

The even balances and lever balances heretofore discussed all have the scale pans suspended from the beams, but for

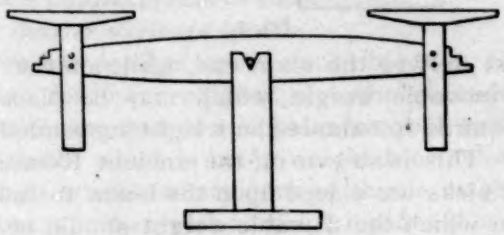


FIG. 9.

many purposes suspended scale pans are inconvenient, and upright pans supported above the beam are desired.

Returning to our model, we rigidly attach two pans to the beam, by pinning each pan support to the ends of the beam by two pins (*Fig. 9*). We now place a pound weight on the centre of each pan, and the scale balances correctly. But if we move one of the weights a fraction of an inch outwards from the centre of the beam, the beam will be depressed on that side, an effect exactly the same as would follow from moving outwards the sliding weight on the lever balance. This method of attaching the pans is therefore incorrect, and the balance as thus constructed is a failure. In order to make a successful upright-pan balance, it is necessary to allow the pan supports freely to move on the end pivots of the beam, instead of rigidly attaching them to it, and at the same time to insure that they retain a vertical position, no

matter what deviation from the horizontal the beam may take in its oscillation. This is accomplished by adding to the structure a parallel motion, which we do on the model by placing a second beam, a duplicate of the first, underneath the latter, and pinning each pan support near its lower end to this lower beam, by one pin, and near its upper end by one pin to the upper beam, so that while both beams oscillate together the pan supports, slightly rotating on the pins, preserve a parallel and vertical position (*Fig. 10*). If we now place a pound weight on each pan, the scale will balance as before, but if we move either weight to any side or corner of the pan, it will still balance, eccentricity of loading having no effect to disturb the equilibrium. This is the principle of all upright-pan pivot balances. In ordinary knife-edge

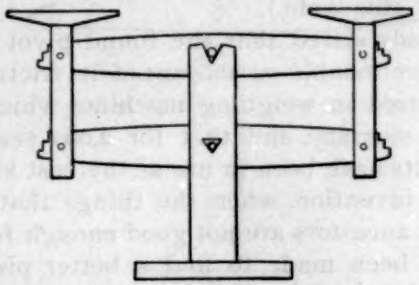


FIG. 10.

upright-pan scales, such as the one shown on the table, an ordinary grocer's counter scale, the lower beam is hidden in the casting, close to the table, and here it takes the form of a slender rod, pivoted to the central support and to the pan supports by round pin pivots instead of knife edges. The lower beam is sometimes made in two parts, being cut in half in the middle of its length, each half being separately pivoted to the central support. Each half of the lower beam is then called a radius arm.

The same principle is adopted in upright-pan lever or steelyard balances, such as the small Fairbanks' letter scale here shown, only one-half of the lower beam, or one radius arm being needed in this case to keep the pan support vertical, since there is only one pan and one pan support used in this style of balance.

The modern platform scale, which was invented by Thaddeus Fairbanks more than fifty years ago, is a compound lever balance. Imagine four of these small steelyard scales placed at the four corners of a rectangle, their graduated beams all pointing towards the centre, where they are separately connected to four strings tied one to the end of each beam, the four strings tied together into one a short distance below, and carrying a pan for holding weights. A flat plate or board may now be placed on top of the four scales, its four corners resting one on each scale. We now have a crude representation of the main principle of the platform scale. I have here an actual platform scale, of the same general style as Fairbanks', which is made by Riehlé Brothers, of this city. (The lecturer here described the construction of this scale.)

I have already stated that the round pivot for balance scales is so objectionable on account of its friction that it is almost never used in weighing machines which have any pretension to accuracy, and that for 2,000 years, or more, knife-edge pivots have been in use as the best kind of pivot. In this age of invention, when the things that were good enough for our ancestors are not good enough for us, many attempts have been made to find a better pivot than the knife edge, which shall be free from the objections of the friction which is a necessary defect of its action, even when new and finely finished, but especially of its want of permanency, the knife edge being extremely susceptible to injury from crushing, bruising, the action of the atmosphere, dust, etc. In quite recent times these attempts have met with success, and I now have the pleasure of exhibiting some forms of pivot balance in which knife edges are dispensed with.

The flexure pivot balance.—The first of these is the flexure pivot balance, which I will show by attaching a flexure pivot to the wooden model which has already done us such good service (*Fig. 11*). I have here two short pieces of flat spring steel, which are clamped tightly in two small vises or clamping pieces, so that about half an inch of each strip is left exposed between the faces of the

clamps. Attaching one clamp to our model beam, and one to the pedestal, you notice that the beam oscillates freely, by bending slightly the thin steel strips. I have copies of two English patents, one by J. M. Taurines, of Paris, dated December 18, 1861, and one by Frederick D. Artingstall, of Manchester, dated September 8, 1862, which show and describe balances made on flexure pivots very similar to the one here shown, but I am not aware whether Mr. Taurines or Mr. Artingstall ever made weighing machines for the market on this principle, although it would appear that practical weighing machines might be made under their patents, provided that sufficient mechanical skill were used in the details of construction. In 1872 and also in

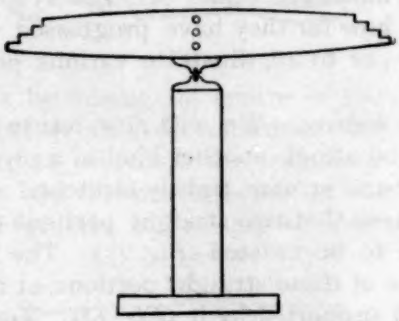


FIG. 11.

1883 and 1884, Mr. A. H. Emery obtained patents on weighing machines, in which are combined the principles of the flexure-pivoted beam and the hydrostatic balance with flexible metallic diaphragms, which has already been referred to. In 1879 Mr. Emery completed, at a cost of over $100,000, his famous testing machine on this combination of principles, which has since that date been in the service of the United States Government, at the Arsenal at Watertown, Mass. It is used for testing the strength of metals and other materials of construction, and has a capacity of 800,000 pounds for strains of either tension or compression, and can test specimens of any length up to thirty feet. A very complete description of this remarkable testing machine was published in a pamphlet entitled, "A New

System of Weighing Machinery," issued in 1884, by the Yale & Towne Manufacturing Company, of Stamford, Conn. From this pamphlet I have taken a few cuts which I will show on the screen.

The Yale & Towne Manufacturing Company, made a number of testing machines under the Emery patents, of capacities ranging from fifty to 150 tons, one of which is also shown on the screen. They also made a few platform scales of large capacity on the same principle, but I believe these have not yet been brought into regular use, nor have any small weighing scales for ordinary uses yet been put on the market on the flexure principle. Messrs. Wm. Sellers & Co., of this city, have recently secured the right to build testing machines under Mr. Emery's patents, but I am not aware how far they have progressed in their manufacture. *Figs. 12* to *16*, illustrate various portions of this machine.

The torsion balance.—We will now return to our model beam again, and attach another kind of a pivot, which consists of a flat band or wire tightly stretched around an iron frame or truss, so that two straight portions of the endless band are free to be twisted (*Fig. 17*). The beam is firmly clamped to one of these straight portions, at right angles to its length, and supported by it (*Fig. 18*). You observe that as the beam is oscillated, the wire or band twists, hence the name, the Torsion Balance. Professors Gauss and Weber, of the University of Gottingen experimented upon balances with a twisting wire for a pivot a good many years ago, but their experiments and those of some others were so unsuccessful, that the Encyclopædia Brittanica states that if used for large weights the beam would have to be supported by knife edges and bearings, and that, therefore, the torsion balance has no *raison d'etre*. One of the causes of the failure of the earlier experiments was the want of a correct way of stretching the wire. This was remedied in 1882 by the late Prof. Frederick Roeder, of Cincinnati. A greater trouble, however, and one which seemed to be fatal to the hopes of the torsion balance, was the fact that as soon as the torsion band or wire was given sufficient size to make it strong

enough to carry a desired weight, the elasticity of the wire became so great as to destroy the sensitiveness of the balance. Dr. Alfred Springer, Prof. Roeder's associate, discovered that the objectionable effect of the elasticity of the wire could be entirely overcome by making the beam "top-

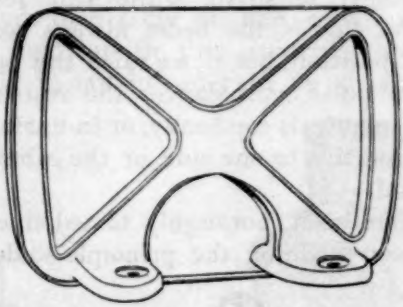


FIG. 17.

heavy," that is by raising its centre of gravity above the point of support or axis of oscillation. He thus used the force of gravity to overcome the resistance of the wire to being twisted. On this model beam we can raise or lower the centre of gravity by raising or lowering the poise

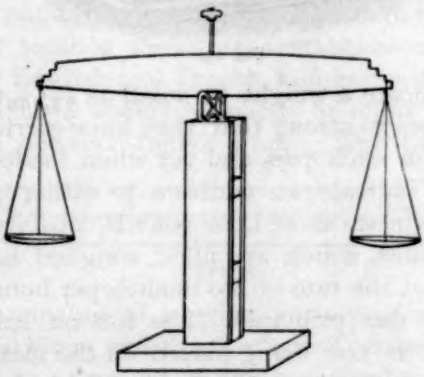


FIG. 18.

weight which is carried on a screw bolt above the centre of the beam. On removing the poise weight we notice that the beam oscillates quite rapidly, say twice every second, while the weight of a penny placed on one end of the beam has little appreciable effect in depressing that end. If we

now raise the centre of gravity of the beam, by placing the poise ball on the screw, the oscillations decrease to ten or less per minute, and a penny placed on one end deflects the beam through a large angle. By raising the poise a little, we decrease the rate of oscillation still more, and the beam becomes exceedingly sensitive, while still remaining in stable equilibrium, that is, the beam always comes to rest in the horizontal position, but if we raise the poise too far the gravity of the poise overbalances the resistance of the elastic wire, the balance is top-heavy, or in unstable equilibrium, and the beam tips to one side or the other, but never remains horizontal.

This system has been thoroughly tested since 1882, and balances have been made on the principle so delicate that

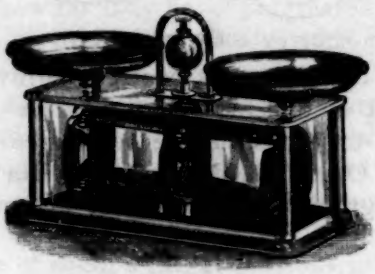


FIG. 19.

they would indicate a weight as small as $\frac{1}{25,000}$th part of a grain, and others so strong that they have carried a weight of 500 pounds on each pan, and yet when loaded with that weight would indicate an addition to either pan of two grains. Platform scales of 1,000 pounds capacity, and automatic grain scales, which are filled, weighed and dumped automatically, at the rate of 200 bushels per hour, have also been made on this principle. The torsion balance in its improved form is now being placed on the market by The Springer Torsion Balance Company, which has recently built a new factory especially for its manufacture in Jersey City. I have several samples of various styles on the table, which may be examined at the close of the lecture. The druggist's counter scale (*Fig. 19*) has a working capacity of twenty pounds on each pan and will indicate an addition of

half a grain. This scale has now been on the market nearly two years. The small letter scale, eight ounces capacity (*Fig. 20*), is only a few weeks old, and the prescription scale (*Fig. 21*), which is the most recent improvement on one which was introduced two years ago, may be called an advance copy of one which will be put on the market next month, this particular scale having been finished only to-day in order to be shown here to-night.

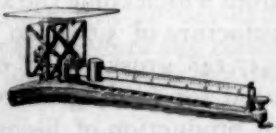


FIG. 20.

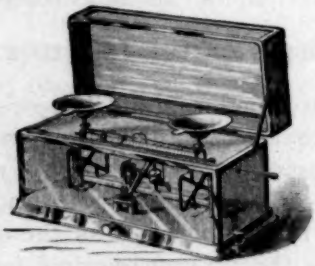


FIG. 21.

It contains a new style of sliding weight or rider beam for small weights (*Fig. 22*), a beam engraved on its upper edge for weights from one-eighth grain up to eight grains, and on its lower edge from one-half centigram to five decigrams, so that this balance shows an instantaneous comparison between the English and French weights within this range. The balance has a working capacity of eight ounces, and is sensitive to one-sixty-fourth grain. The torsion balance

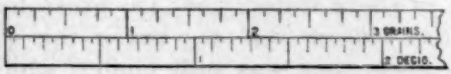


FIG. 22.

principle is capable of a great variety of applications in weighing machines, and the Springer Torsion Balance Company expect to bring out a number of other forms during the present year.

(The lecturer closed by exhibiting and explaining samples of torsion and other balances, and answering questions concerning them.)

THE IRON ORES OF THE UNITED STATES.

BY JOHN BIRKINBINE, Mining Engineer.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *December 9, 1887.*]

Mr. BIRKINBINE was introduced by the Secretary of the INSTITUTE and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

In considering the iron ores of the United States it is essential that we first note the sources from which come the supply of mineral consumed in the manufacture of 5,683,329 gross tons of pig iron in 1886 and 6,417,148 gross tons* of pig iron in 1887, as well as the ore used for fettling in rolling mills, the amount required for the production of blooms by direct processes, bloomeries and other purposes. Probably 11,500,000 gross tons of iron ore were used in this country in 1886, and the estimate for 1887 is 13,000,000 gross tons.

A careful investigation of the consumption of iron ore and the production of pig iron in the United States, shows that the average yield of ore as charged into the blast furnaces of the country is about fifty-one per cent., therefore a little less than two tons of ore are required on the average to produce one ton of pig iron. The output of 577 blast furnaces, in 1886 was, as above stated, 5,683,329 gross tons, requiring 11,300,000 gross tons of iron ore; but of this quantity probably 300,000 gross tons was mill cinder, which deducted, leaves 11,000,000 gross tons of iron ore used by our furnaces, to which we should add 500,000 gross tons consumed in bloomery fires, or used as fettling, or as flux in smelting the precious metals and other purposes, making a grand total

* Since the lecture was delivered, the statistics of iron and steel production in 1887, issued by the American Iron and Steel Association, have been published, and returns from some of the iron mines or mining districts have been obtained, therefore in the text the actual figures for 1887 are given in place of the estimates which were made in the lecture, and the year 1887 is mentioned as last year. J. B.

of 11,500,000 gross tons. Similar estimates give the probable consumption of iron ore in 1887 as 13,000,000 gross tons, of which nearly ten per cent. was foreign ore.

There is in northern New York and in some of the Southern States a limited industry where iron ores are converted into "loupes" and hammered into blooms in open "bloomary" fires, sometimes called "Catalan" forges, after the ancient method pursued in Catalonia, Spain. The amount of iron produced in this way in 1887 was but 15,088 net tons, or 13,471 gross tons. Various "direct" processes, which have been and are still being experimented upon, and upon which so much time and money have been expended with so little practical result, also used some ore. Our attention will be devoted entirely to smelting in the 583 blast furnaces of the country, the great bulk of our domestic iron ores, as well as the foreign ores brought into the United States.

There are to-day in the United States 676 blast furnaces, but ninety-three of these have been dropped from the official record by reason of having outlived their usefulness, or having failed to keep pace with the march of improvement, which raised our blast-furnace practice to a standard which commends the admiration of the world. This leaves a total of 583 blast furnaces on the active list.

COMPOSITION OF IRON ORES.

Enthusiasts or novices still occasionally claim an ore yielding eighty to ninety per cent. of iron in spite of the fact that the magnetic oxide or proto-sesquioxide of iron (Fe_3O_4), the base of our magnetites, and the richest ore which can be obtained consists of 72·4 per cent. iron and 27·6 per cent. oxygen; and the sesquioxide of iron or ferric oxide (Fe_2O_3), the base of all our hematites, is a combination of seventy per cent. iron and thirty per cent of oxygen. There is also the protoxide of iron or ferrous oxide (FeO), containing nearly seventy-eight per cent. of iron, but this does not exist in our ores except in combination, as in the carbonate of iron ($FeOCO_2$ or $FeCO_3$). However, all the ores are mixed with earthy or rock gangue and carry sulphur, phos-

phorous, manganese, titanium and more or less water, and seldom approximate theoretical purity. The most notable instances of this approach being in large crystals of magnetite from near Port Henry, N. Y., and Republic, Mich., and in the harder specular ores of Michigan and Minnesota.

Notwithstanding the high proportion of iron in magnetic oxide, the red hematites mined in this country are, as a class, the richest ores in iron which we produce. This is largely due to the dissemination of crystals of magnetic ore through the gangue, or their mixture with other crystals, requiring in many cases the reduction of the ore to small size, and the separation by gravitation or by magnetism of the particles.

The red hematites differ only from the brown hematites in the former carrying less water than the latter, and the subdivision of the brown hematites into "turgite," "goethite," "limonite" and "bog ore," etc., is mainly due to the water they contain, and the more or less intimate mixture of the peroxide and earthy matter. Of the red hematites the "specular," "micaceous," "dye stone," and "fossil" ores are determined by physical structure or association with gangue.

The carbonate iron ores are also classed as "siderite," "clay iron stone," "black band," "kidney ore," etc., in various localities.

The carbonates are based on the combination of carbonic acid and ferrous oxide, above referred to, and if existing pure as $FeCO_3$ would contain 48·27 per cent. of iron, but these generally occur in connection with carbonaceous matter.

DISTRIBUTION OF IRON ORES.

An enumeration of the localities from which American iron ores are obtained, and a discussion of the peculiarities of occurrence, formation or composition of the various ores, would require a course of lectures, and therefore in a single evening no attempt, other than to cover the ground generally, will be made. In twenty-six states and territories iron ores are now mined, and in most of the others deposits of mineral are known to exist in workable quantity.

In every state east of the Mississippi River, with the exception of Florida and Mississippi, iron ores have been or are now mined, and in Mississippi I lately inspected a weathered carbonate, covering considerable territory. A deposit of bog ore in Florida is now being investigated and plans for a blast furnace to utilize it, drawn. Of the other states, we immediately recognize Minnesota and Missouri as containing a wealth of excellent ores. Iowa and Arkansas, Louisiana and Texas have known deposits as yet undeveloped, although in the last named state some of the ores in the northeast section have been smelted. A sample of excellent brown hermatite, probably a weathered carbonate from near Council Bluffs, and a limonite from central Iowa, were lately received.

Of the Western States, Colorado, Utah, California, Oregon and Washington Territory have produced ores, and deposits of mineral are reported in other territories. In fact it would be unwise to assert that iron ore does not exist in workable deposits in any one of the political subdivisions of the United States, and our neighbors of Canada, Mexico and Cuba can boast of remarkable supplies of this mineral. Some of the Canadian iron ores have been exploited by American capital, the output being shipped into this country, and efforts are now being made to develop other deposits for home consumption. Mexico has its unrivalled iron mountain, the Cerro de Mercado, at Durango, and numerous minor deposits throughout the Republic, and the development of the iron ore on the south shore of the Island of Cuba, near Santiago de Cuba, in which some of our large steel companies are interested, is now well known.

In locating in a general way the deposits of iron ores no attempt will be made to point out on the map * those which have been reported as existing in the western portion of the continent, for but few have been worked, and information as to the numerous favorable showings is not sufficiently definite to be reliable. We may, however, note that an iron industry exists at Port Townsend, in Washington Territory,

* The lecturer indicated on a large map the general position of the various iron ores, and designated the position of the more prominent mining districts.

for which some ore is obtained locally, and some from Texada Island, British Columbia, and an English syndicate is now constructing a large steel plant at Seattle, Wash. T. At Osewego, Ore., and at Clipper Gap, Cal., there are blast furnaces (now inactive) but for which local brown hematites form the bases of supply. The most important Western development is at South Pueblo, Col., where various Colorado ores are smelted. Iron on a small scale has also been made in Utah, and considerable iron ore is used throughout the West in silver smelting. A general summary of the present exploited iron ore deposits east of the Rocky Mountains is as follows:

MAGNETITES.

Magnetites abound in Canada and occur in Maine, Vermont, New Hampshire and Rhode Island, but the most northerly deposits at present worked in quantity are in the Lake Champlain region. The Chateaugay, Port Henry and Crown Point mines, the most noted of these, lie from 1,200 to 2,000 feet above the lake, and from seven to thirty miles westward. Some magnetites have, however, been found close to Lake Champlain, and others are on the western slope of the Adirondack mountain range. A few of these ores are of the Bessemer grade, but it is believed that more can be made so by crushing the ore and separating the apatite (phosphate of lime) from the iron crystals. Concentration and separation is now carried on to a large extent, and the use of fine ore in the blast furnace is causing no serious trouble. Considerable magnetic ore sand is found along the coasts of California and Long Island Sound, some of which has been separated by magnetic machines, and it has been claimed that the sub-aqueous deposit from whence these sands emanate affect ship's compasses; in fact, Mr. Edison attributed the loss of the *Oregon* to such magnetic disturbances.

The Lake Champlain district produces about 500,000 tons per annum, and up to date is credited with having yielded 13,500,000 gross tons of ore, which has been smelted in blast furnaces or reduced by the direct process in bloomary fires. An area of one-half square mile west of Port Henry has, it is claimed, produced 3,500,000 gross tons of ore.

Some deposits of magnetite in northern New York, which indicate rich ore in quantity, carry so much titanium as to seriously interfere with their smelting in the present state of our knowledge of ore concentration and blast furnace practice, but this, like other drawbacks, will be overcome.

Magnetites occur again in southeastern New York, in Putnam and Orange Counties, within fifty miles of New York City, those of the former county, such as the Tilly Foster and Croton Mines, being prominent, owing to peculiarities of formation and composition. Some are apparently large lenses or chimneys of ore with faults, making mining expensive. The annual output of these mines approximates 45,000 tons.

Tracing the magnetites from southern New York into northern New Jersey, we find numerous mines in that state producing in the aggregate over 500,000 gross tons per annum, and having in their history added about 16,000,000 gross tons to our ore supply. Many of these ores are high in sulphur and require roasting. In northern New Jersey "franklinite" occurs. This is an ore containing zinc, manganese and iron which is smelted in small furnaces to produce "speigeleisen" after it has been roasted, to remove the zinc, as zinc oxide. Occasionally very large crystals (with faces of five inches) of franklinite are found. The Lake Champlain region has been worked since 1804, and the New Jersey magnetic mines have been producers for over a century.

Following the ranges of hills into Pennsylvania, the magnetic iron ores occur along the South Mountain, the prominent deposits in this state being at Boyertown, along French Creek, at Cornwall, and at Dillsburg. The Cornwall ore hills are worked above the water level, and are practically on elevated ground. The deposit is unique, consisting of a mass of magnetic ore, confined by trap walls forming three hills, and is mined more cheaply than any ore of similar grade in the country. The Cornwall ore, while sufficiently low in phosphorus for Bessemer steel purposes, carries, on an average, two per cent. of sulphur, which is partially removed by roasting in kilns with waste coal.

The Cornwall ore hills have been worked for over 150 years, and the aggregate output to date is 8,673,000 gross tons, of which 687,210 gross tons were mined in 1887.

The general topographical and geological structure continuing through Maryland, Virginia, North Carolina, South Carolina, Georgia, Alabama and Tennessee, magnetites are found in these states, the largest developments being in North Carolina, notably at the Cranberry mines in the western and a titaniferous deposit in the central portion of the state.

(It was in North Carolina that the first discovery of iron ores in this country was made three centuries ago, in 1585, but the first iron ore shipped from America came from Virginia in 1608.)

Ores exist in the western part of South Carolina, and a century ago smelting of these was introduced in that state, but for thirty years there has been no iron made there.

This general group of ores just mentioned comprises practically all the magnetites exploited east of the Rocky Mountains, except occasional deposits in the north peninsula of Michigan and in Missouri; in these cases the magnetites occur with specular red hematites.

With the exception of Cornwall and one or two other deposits the magnetites are mined underground, a depth of 300 to 800 feet having been obtained in some of the workings of the Lake Champlain, the New Jersey and the Pennsylvania mines. But few American magnetites are free from sulphur, phosphorus, copper or titanium.

RED HEMATITES.

The most important operations in mining red hematites are in the Lake Superior district, but to indicate the geographical distribution of this class of ores we may first trace them from northern New York, where a considerable industry has been maintained in mining specular ores, into central New York, where the fossil ores known as "Clinton fossils" are wrought. These latter occur again in Pennsylvania, near Danville, and extend through the central part of the state, supplying stock to numerous blast furnaces; then through

Maryland, Virginia and West Virginia into eastern Kentucky and Tennessee, being recognized in the latter state as "dyestone ores," and showing their greatest development in Alabama and Georgia. These ores being the basis of supply for the Birmingham, Alabama, furnaces are there known as "Red Mountain" ore.

A peculiar and apparently isolated deposit of Clinton fossil ore exists at Iron Ridge, about fifty miles north of Milwaukee, Wis.; here the ore soon after mining breaks into grains which, from their shape, size and color, have given to it the name of "flaxseed ore." Another deposit of fossil ore is reported further north in Wisconsin. The Iron Ridge ore carries such proportions of phosphorus, lime, and silica, as to invite attention to it for use in producing steel by the basic process.

The Lake Superior red hematites are of the hard and soft varieties, the Marquette district of Michigan and the Vermilion district of Minnesota showing the former, and the Menominee and Gogebic districts of Michigan and Wisconsin exhibiting chiefly the softer varieties, although soft ores may occur among the harder and *vice versa*.

The noted deposits at Iron Mountain and Pilot Knob, Mo., are speculars with some magnetites, and in the central part of that state excellent soft, red hematites abound. Ores of this class are also reported in Arkansas and Texas. Many of the Bessemer ores of the United States are red hematites, but such ores low enough in phosphorus for this process are the exception rather than the rule. The purest of these ores command the highest market rates, being shipped fully 1,500 miles, in some cases by water and rail. The Chicago, Cleveland, Pittsburgh, Wheeling and adjacent blast furnaces depend principally upon the red hematites of the Lake Superior district, and large shipments are made to Troy, N. Y., and into eastern Pennsylvania.

One of the recognized conditions of an iron ore suitable for the manufacture of Bessemer pig iron is that it shall not contain over one part of phosphorus to 1,000 of iron, but there are cases where ores have been condemned because of an excess of phosphorus, or chemists have been blamed for imperfect analyses where neither the ore or the analyst were

at fault; but the fuel used in smelting the ore in the blast furnace or in melting the iron in a cupola was credited with low phosphorus when it carried a liberal amount; in fact, where low phosphorus is required it is as important to analyze the fuel as the ores or iron for this component.

BROWN HEMATITES.

The brown hematite ores are liberally distributed and are mined in most of the states. The earlier iron industry of the country was sustained principally from the bog variety along the sea-coast, but as the settlements extended westward the use of these lean ores was abandoned.

The Salisbury region, embracing portions of western Massachusetts and Connecticut and eastern New York, has an unrivalled reputation for pig-iron for special purposes produced from brown hematites. These ores also abound in the Lehigh, East Penn, Cumberland and other Pennsylvania valleys, passing thence into Maryland, through the Shenandoah, New River and Cripple Creek Valleys of Virginia into North Carolina, Tennessee, Kentucky and Alabama, forming in the latter the principal support of the charcoal iron-producing industry. To the brown hematites we owe much of the prominence Pennsylvania has won as an iron centre and from them our foundry irons, car-wheel metal, boiler plate and other specialties have been prepared. A widely distributed deposit of excellent brown hematite occurs in Northern Texas and Louisiana, and outcrops of what are apparently hematites along the Mississippi and Missouri and their tributaries in Mississippi, Tennessee, Missouri, Iowa, etc., are probably weathered carbonates.

Ores of this class are also obtained in Maine, in Rhode Island, on Staten Island, in Delaware, Maryland, Florida and other states.

The brown hematite often occurs in connection with the red hematite. As far as has been exploited, the richest ores of this class are in the Salisbury district, of New England, in southwest Virginia, middle Tennessee and Kentucky, northern Georgia and eastern Alabama, but some other deposits, but slightly developed, offer favorable indications as to quality.

CARBONATES.

The carbonate iron ores are generally esteemed as the least reliable of all varieties; they have been the main dependence of the Baltimore iron industry, and occur between Baltimore and Washington as kidneys in clay. They were the instigating cause of the establishment of our western Pennsylvania blast furnaces, as at Johnstown and in the Monongahela and Shenango Valleys. Ohio has few ores that are not carbonates and to these ores the large developments of the Mahoning Valley, the reputation of the Hanging Rock region and the sudden rise into prominence and nearly as sudden decline of the Hocking region is to be credited.

In using this variety of ore, it is generally roasted to drive off the carbonic acid, and other ores are often similarly treated to eliminate the sulphur they contain.

The carbonates are widely distributed and form an important factor in our iron production. They can be traced through New York, Pennsylvania, Ohio, West Virginia, Virginia, Kentucky and Tennessee, into Alabama and Mississippi, and are found in Arkansas, Missouri, Iowa, etc.

The black-band variety is used to a limited extent, but the cheerful outlook which encouraged a large investment of home and British capital to secure in this country similar results to those obtained from these ores in Scotland was not verified in practice.

MILL CINDER.

In the production of puddled and rolled iron, the resultant cinder which carries off silica, phosphorus, etc., contains from fifty to sixty per cent. iron, and this otherwise waste material is utilized in the manufacture of pig iron by mixing it with natural ores. Owing to prejudice its use is seldom referred to, and yet there are probably not over four mines in the country which contribute so much towards the manufacture of pig iron as this slag or cinder. In some portions of Germany, mill cinder is roasted before it is charged into the blast furnaces.

To a limited extent the residuum from iron pyrites (Fe S), after the sulphuric acid is extracted, is used for the production of iron; this is commercially known as "purple ore," or "blue billy," and is employed in Great Britain more than in this country.

RÉSUMÉ.

It is not presumed that in this hasty sketch all of the iron ores east of the continental divide have been referred to, nor is it possible in the limited time at command to even enumerate the prominent features of the more important ones.*

As mined and supplied to our blast furnaces, the various classes of ores yield about as follows:

Magnetites, . .	from 45 to 67	per cent iron.		Average 56	per cent.		
Specular and fossil ores (red hematites), .	" 35 to 68	"	"	" 57	"		
Brown hematites, . . .	" 35 to 55	"	"	" 42	"		
Carbonates, raw,	" 25 to 40	"	"	" 32	"		
Mill cinder, ...				" 54	"		
Foreign ores, ...				" 53	"		

In 1884, the American Iron and Steel Association determined by careful investigation that, eliminating from the calculation the mill cinder used, the ore employed to produce pig iron in the United States averaged 2·03 tons per ton of iron made, being less than was required in other countries; Great Britain averaging 2·4 tons; Germany, 2·6 tons; France, 2·6, and Belgium, 2·7 tons. Since that time a larger proportion of richer ores have been employed in America and it is probable that our average consumption is slightly below two tons of ore per ton of pig iron.

It is perhaps unnecessary to remind you that the most important source of our ore supply is from the Lake Superior region, the output of the four districts embraced in it

* During the lecture a number of lantern slides were exhibited, reproductions of photographs of numerous prominent iron mines, showing the extent of the deposits and the methods of working them, etc. A geological and topographical model of the Cornwall ore hills of Pennsylvania was also shown.

being sufficient to produce forty per cent. of the pig iron which we make. About thirty-six per cent. of the iron ore mined in the United States in 1887 came from that region, and owing to the high percentage of iron in these ores, their aggregate, 4,667,652 gross tons, was sufficient to produce nearly forty-three per cent. of the pig iron made in the United States last year.

FOREIGN ORES.

Next to the Lake Superior region comes the foreign ores, 1,039,433 gross tons having been imported in 1886, and the returns for 1887 show that we received 1,194,301 gross tons. Some of these ores come from our neighbors in Canada and Cuba, but the major portion was from Spain, Africa, the Island of Elba, Greece, France and other countries across the ocean. Notwithstanding the fact that the United States imported more largely than ever before in 1886, and a still greater amount in 1887, the proportionate quantity of foreign ores per ton of pig iron made was, until 1887, less than in 1881, and we to-day use relatively less foreign ores than any of the prominent iron producing countries, as is exhibited by the following table.

Iron production and iron ore imports in different countries in eight years:

UNITED STATES.

Years.	*Pig Iron Made.*	*Iron Ore Imported.*	*Average Amount of Ore Imported per Ton of Iron Produced.*
1879,	2,741,853	284,141	·104
1880,	3,835,191	493,408	·129
1881,	4,144,254	782,887	·189
1882,	4,623,323	589,655	·128
1883,	4,595,510	490,875	·107
1884,	4,097,868	487,820	·109
1885,	4,044,526	390,786	·086
1886,	5,683,329	1,039,433	·183
Total,	33,765,854	4,559,005	·135
1887,	6,417,418	1,194,301	·183

GREAT BRITAIN.

Years.	*Pig Iron Made.*	*Iron Ore Imported.*	*Average Amount of Ore Imported per Ton of Iron Produced.*
1879,	5,995,337	1,083,692	·181
1880,	7,749,233	2,634,401	·340
1881,	8,377,364	2,449,277	·292
1882,	8,493,287	3,282,496	·386
1883,	8,490,224	3,178,310	·321
1884,	7,528,966	2,728,672	·362
1885,	7,250,657	2,817,597	·389
1886,	6,870,665	2,875,176	·418
Total,	60,755,733	21,097,621	·346

FRANCE.

Years.	*Pig Iron Made.*	*Iron Ore Imported.*	*Average Amount of Ore Imported per Ton of Iron Produced.*
1879,	1,400,286	941,812	·673
1880,	1,733,102	1,168,215	·674
1881,	1,894,861	1,287,870	·680
1882,	2,039,067	1,425,870	·699
1883,	2,069,430	1,601,217	·774
1884,	1,855,247	1,412,724	·762
1885,	1,630,648	1,419,521	·871
1886,	1,507,850	1,158,581	·768
Total,	14,130,491	10,415,810	·737

GERMANY.

Years.	*Pig Iron Made.*	*Iron Ore Imported.*	*Average Amount of Ore Imported per Ton of Iron Produced.*
1879,	2,226,587	380,000	·171
1880,	2,729,038	607,007	·222
1881,	2,914,009	615,490	·211
1882,	3,380,806	785,360	·232
1883,	3,469,719	800,373	·231
1884,	3,600,612	980,442	·272
1885,	3,687,316	852,714	·232
1886,	3,339,803	812,635	.243
Total,	25,347,890	5,834,029	·230

BELGIUM.

Years.	*Pig Iron Made.*	*Iron Ore Imported.*	*Average Amount of Ore Imported per Ton of Iron Produced*
1879,	448,371	614,534	1·373
1880,	595,704	921,784	1·548
1881,	624,736	1,169,206	1·872
1882,	727,000	1,206,717	1·66
1883,	783,433	1,612,469	2·058
1884,	750,812	1,488,140	1·982
1885,	712,876	1,393,601	1·96
1886,	697,110	1,365,939	1·959
Total,	5,340,042	9,772,390	1·83

This table demonstrates that, although our importation of iron ore reached its maximum in 1887, the amount of foreign ore used closely approximated in 1886 the proportion used in Great Britain in 1879, since which date that country has continued to rely on foreign ores to a much greater extent than the United States. The same remark holds true concerning Germany, and France has been more dependent upon foreign ores than any of the countries named, except Belgium, which relies almost entirely upon ores mined outside of its borders.

Taking the average of eight years for the United States, Great Britain and France, Belgium and Germany, and assuming that the average yield of ore, as reported by Mr. Swank, from actual returns made by our blast furnaces in 1884, holds good for the entire period, we have the following:

	United States.	*Great Britain.*	*France.*	*Germany.*	*Belgium.*
Tons of ore required to make one ton of pig iron,	2·03	2·4	2·6	2·6	2·7
Tons of foreign ore imported per ton of pig iron made,	·135	·346	·737	·230	1·83
Average percentage of foreign ore to total ore used,	6·65	14·33	28·37	8·85	67·78

From this it is evident that the United States not only uses a less proportion of foreign ore than any of the other countries named, but the product of our domestic mines averages so well that we need less ore per ton of pig iron than other countries.

We can justly attribute a part of this showing to the influence of the specific duty of seventy-five cents per ton on foreign ores, which undoubtedly encourages a higher average percentage than would be the case if a lower or an *ad valorem* duty was laid on the ores. In fact, we now receive chiefly the best of the foreign ores, for the more valuable the material the lower the proportionate charge for duty.

PROMINENT IRON ORE PRODUCERS.

Next to the foreign ores, the Cornwall ore hills of Pennsylvania ranks as a source of supply and the company operating this unique deposit, which in 1887 mined 667,210 gross tons of magnetite, is the largest producer of iron ore in the country.

The Lake Champlain district follows next, and the product of the mines of magnetic ore sent from Plattsburgh, Port Henry and Crown Point aggregating, in 1886, 663,752 gross tons, and in 1887, 788,084 gross tons.*

To show the relative importance of the various regions, the following statement has been prepared. In it the output of the four districts, comprising the Lake Superior region, are given separately, and each region is placed in the order of its prominence in 1886. Where data were at hand the actual output, and in other cases estimates of the probable production of 1887 are given:

SOURCE OF IRON ORE SUPPLY BY DISTRICTS.

	GROSS TONS.	
	1886.	*1887.*
Marquette District, Lake Superior Region,	1,621,887	1,836,953
Imported Iron Ores,	1,039,433	1,194,301
Menominee District, Lake Superior Region,	880,006	1,198,743
Gogebic District, Lake Superior Region,	756,281	1,237,704
Cornwall Ore Hills, Pennsylvania,	688,054	667,210
Lake Champlain magnetites,	663,752	788,084
New Jersey magnetites,	500,501	547,889
Missouri mines,	379,776	427,785
Ohio ores, carbonates and hematites,	344,480	377,465
Vermilion Lake District, Minnesota,	304,396	394,252
Cranberry Mines, North Carolina,	24,106	45,032

* Messrs. Witherbees, Sherman & Co., the largest individual firm of ore producers in the country, offer for sale, in 1888, 375,000 tons of ore from the mines near Port Henry, N. Y.

The following estimates are based upon an average yield of ore and pig iron production in 1886:

	GROSS TONS.	
	1886.	*1887.*
Alabama,	670,000	740,000
Tennessee,	470,000	600,000
Virginia,	380,000	450,000
Georgia,	95,000	105,000

It will be noticed that the Gogebic range outstripped the Menominee range in 1887, owing to the unusual activity in opening mines, and that the Lake Champlain district shipped more ore than the Cornwall Ore Hills in 1887.

The following shows the approximate total production of iron ore to date in prominent mining centres.

Lake Superior Region (thirty-two years),		35,700,000
Of which Marquette District supplied,	25,200,000	
" Menominee " "	7,500,000	
" Gogebic " "	2,000,000	
" Vermilion " "	1,000,000	
Lake Champlain Region, N. Y. (eighty-four years),		13,500,000
Of which Port Henry supplied,*	8,000,000	
" Crown Point "	1,500,000	
" Chateaugay "	2,000,000	
" Other mines "	2,000,000	
New Jersey (about 100 years),		16,000,000
Cornwall (about 140 years),		7,900,000
Missouri,		
Iron Mountain supplied,	2,750,000	
Pilot Knob and other mines,	1,250,000	

From the Chapin, Norway and Vulcan mines were won nearly one-half of the product of the Menominee range. While almost seventy per cent. of the output of the Gogebic range came from the Colby, Norrie, Ashland and Aurora mines.

TONNAGE.

The mining of iron is a business of considerable importance, and to appreciate its volume we may estimate the

*Six Marquette mines, viz: Lake Superior, Cleveland, Republic, Jackson, Champion and New York produced over sixty per cent. of the total output of this district.

railroad traffic which it represents, although all of the ore does not pass over railroads and much of it reaches the blast furnaces by both rail and water transportation. The majority of the ores from the Lake Superior region are carried by rail to shipping ports, thence by vessel to the lower lake ports and there rehandled into cars which travel over the railroads to the blast furnaces. Several blast furnace plants are located so as to unload foreign ores at their docks, but most of the foreign ore is transported from the ports where received by railroad cars or by lighters to the points of consumption. A number of our iron works also rely largely on the local deposits, from which the ore is carried by wagons or carts or by wire rope transmission or by tramroad to the furnaces. The proportion, however, of ore which is not hauled over our systems of railroads is quite small, and an illustration of the volume of business based upon the tonnage is a proper one.

Allowing an average load of fifteen net tons per car, which is more probably above than below the actual average, the amount of ore consumed in 1887, viz: 13,063,439 long tons or 14,631,052 net tons, would require 975,404 cars to carry it, or say 32,514 trains of thirty cars each, five such trains, with motive-power and caboose would occupy one mile of track when standing close together, or the year's product would occupy 6,503 miles of track, a distance equal to twice that from New York to San Francisco.

If all this traffic passed a given point there would be eighty-nine trains per day or a train every sixteen minutes during the year.

The traffic of the Pennsylvania Railroad in 1887, as exhibited by the annual report, shows a total tonnage of through freight of 6,278,628 long tons or less than one-half of the total amount of iron ore as above, and the local freight (43,754,669 long tons) is about three times as great, so that the iron ore carried by the different railroads in the United States in 1887 would represent nearly thirty per cent. of the entire freight traffic of the Pennsylvania Railroad and branches for the year.

If now we estimate the labor required to mine the ore, load it on cars, and transport it to destination, we see the importance of this industry, which employs over 50,000 men. But the mechanical appliances used are features of interest, and the hoisting engines, pumps, air compressors, rock-drills, washers and jigs connected with our mines have greatly influenced the advance in mechanical skill which has marked the development of our country.

The tabulated figures presented in this paper indicate the sources from which much of the iron ore is obtained, and from these figures we find that, of the estimated output of iron ore in 1887, the following approximate percentage came from

	Percentage of total output.
Lake Superior Region,	37 —
Foreign ores,	9
Alabama, estimated,	6 —
Cornwall Ore Hills, Pennsylvania,	5
Lake Champlain District,	6
Tennessee, estimated,	5 —
Ohio,	3
New Jersey,	4
Virginia,	4½
Missouri,	3½
Salisbury Region,	1 —
Georgia, estimated,	1 —

From these figures an approximate estimate of the value represented by the iron ore shipment of any one source of supply can be made. As the ores vary in the yield of iron, it will be of interest to place them in something near their relative rank by estimating the probable percentage of the total amount of pig iron which these ores produced.

	Per cent.
Lake Superior ores,	44
Foreign ores,	10½
Lake Champlain ores,	6½
Cornwall ores,	5 —
Alabama ores,	5 —
New Jersey ores,	4½
Tennessee ores,	4
Missouri ores,	3½
Virginia ores,	3 —
Ohio ores,	2½
Salisbury Region,	1 —
Georgia ores,	½ —

The strikes in the anthracite coal regions and in the coke regions during the year, materially reduced the demand for ores, and curtailed the output of some of the important Eastern districts, such as the Lake Champlain, Cornwall and New Jersey mines.

The bulk of the hematites of Pennsylvania, of which we still have large deposits, are but little inferior in the yield of iron, and many are otherwise superior to the Southern ores, and our magnetites and those near us in New Jersey, together with the facility of drawing upon the Lake Superior and foreign countries for their best ores, place Pennsylvania in position to hold her status, and the question of the Keystone State maintaining its pre-eminence as an iron producer, rests entirely with those who manage and control its furnaces.

A BROADER FIELD FOR THE UNITED STATES GEOLOGICAL SURVEY.

By Prof. Persifor Frazer.

Science of May 18, 1888, devotes its first article to a proposition said to be now pending before Congress "to enable the United States Geological Survey to carry on the agricultural work provided for by law." It mentions editorially that "This work falls properly under the scope of a geological survey, as in this case it requires only little additional work to the topographical and geological surveys that are continuously going on, while under any other department it would require the organization of a new survey, and involve great expense." This will commend itself at once to the judgment of all readers. For instance, when Mr. Walcott is pursuing his studies of the first and second fauna-rocks in the wilds of Massachusetts, Vermont, New York and Connecticut, it would but need the addition of an agriculturist to his corps of assistants, to enable him to supplement his very interesting information concerning the Lower Calciferous, by adding that in the much disputed part of the

Taconic area, that disintegration into soil which obscured the real geological sequence from the late Dr. Ebenezer Emmons, is highly conducive to the production of winter wheat and early rose potatoes.

Indeed, it is likely that many of the United States geologists are as expert at horticulture, forestry and agriculture as in the science of which they are the accredited representatives of this country, and many a tedious page of stratigraphy and paleontology might be brightened by sprinkling flowers and ferns over it. In the far West, not only among the arid lands (already described as such by the Director, to the great benefit of our citizens), but on the summits of the most inaccessible peaks, and in the smiling grass valleys, hundreds of miles from any railroad station, the adaptability of the soil for truck gardening, strawberry and peach raising, and the like, might raise a mountain of doubt and uncertainty from the minds of intending immigrants.

The tendency towards consolidation is always a tendency towards economy, and in this case the merging of these very nearly allied investigations is merely forestalling a possible movement on the part of the proposed agricultural department (also pending before Congress) to join to the work of the botanical explorers the duty of settling the distracting questions of the subdivisions of the Archean, the place of the Taconic, and the desirability of a Quaternary Group, to their other researches. Of course it would entail only a little additional work on their part to do this.

Although the statement is not made in explicit terms, it is probable that the United States Geological Survey has neither enough to do nor a sufficient appropriation to do it with. As to the latter, will it be credited that its entire annual expenses, including the printing of the splendid volumes which other nations envy us so much, amount to considerably less than a million of dollars a year? What is this for a country like ours, the broadest in longitude under the sun, and so peculiarly constituted that no sequence in terranes in one part is repeated in any other part, and (according to the conclusions of some of our most frequently quoted geologists) no correlation is possible even between the series of

contiguous areas, not to speak of such remote districts as the Atlantic border, the Mississippi basin, the Rocky Mountain plateau, and the Pacific coast? It follows from this that the United States Geological Survey must establish separate columns—biotic and stratigraphic—wherever these can be found; and as there are thirty-eight states and eleven territories and each state has a number of counties, varying from 175 in Texas to three in Delaware, the possible number of such schemes of classification might reach 1,900.

It is said "possible," because it may turn out that in some cases the scheme of classification established for one county may, with little or no modification, be applied to another; but this cannot be known until the United States Geological Survey has examined them all, and this will require a very long time, owing to their number, and the meagre, not to say parsimonious, appropriation of the Government. It might be thought that the State Surveys could, in their little way, help to reduce this time, and to obviate, so to speak, the necessity for so much Governmental work; but in practice it has been found that no solution of any important question has been satisfactorily reached until the Government officers had been on the ground. At first sight there seems to have been an exception to this in the case of Prof. Dana's work on the Taconic, but this is only apparent; for although the final decision of the official survey was indeed in conformity with the views of the Nestor of American Geology, it was only after it had passed through several successive phases, and consumed several years of unremitting labor, all of which were required before it could be known that Prof. Dana *was* right.

Now that the United States Geological Survey has extended its field of study over the entire United States, including the states with, as well as those without surveys, the conclusion reached by every survey should be submitted to a like test, and this work can scarcely be accomplished in less than a century or two.

But it seems quite reasonable to extend the principle of con-association of the Government scientific work—a sort of syntaxonomy, as it would probably be denominated if

undertaken—still further. If there be an evident appropriateness in collocating the study of the disintegrated rocks with that of the uses of the resulting soil; so (proceeding in the opposite direction) must there be also in uniting with this study that of the orbs which are passing through the various phases already traversed by the little object which is the subject of the investigation of the geologist. In other words, is it not restricting the usefulness of the best equipped and supported organization for scientific purposes under our Government, simply to give it the earth for its study?

Why not transfer the Astronomical Bureau also to it? With only a little additional work the tables of computations for the nautical almanac could be made by the United States Geological Survey, and consistency would be secured by having the broad realm, first pointed out by La Place in all the transformations of its wonderful endogenesis, made the task of one national body to explore and expound, both in its abstract and in its economical relations.

Of course it would follow that navigation, which deals with the problems of travel upon the soft rock forming two-thirds of our little planet, would appropriately fall into one subdivision of the work of the expanded service; and as the Navy Department is entirely dependent upon navigation, this would cease to be necessary as a separate arm of the Government; for the fighting part of this Department could be transferred to a new Military Department, which would find plenty of occupation in protecting parties of explorers against hostile Indians, and standing guard over the geodetic signals which would be erected by the new Survey after its natural and necessary absorption of the Coast and Geodetic Survey within itself.

At least so far in the scheme of centralization we could confidently go, assured of a better and cheaper administration of all their cognate branches by the able Direction, which has hitherto been confined to geology alone.

It may be doubted whether it would be desirable for the present to go farther, but if subsequent events seemed to justify the step, only a little additional work would be needed to enable the reconstructed Geological Survey to supply us

with a Congress to pass appropriations for its maintenance, to build bridges and railroads to help transport its corps, and even to manufacture whatever Nature might seem to have neglected for the purpose of elucidating the Cosmos, and applying it to the needs of the new Survey's constituency —man. P. F.

THEORETICAL AND EXPERIMENTAL DETERMINATION OF THE FOLLOWING DEFINITION OF TEMPERATURE, NAMELY: THE TEMPERATURE OF A BODY IS REPRESENTED BY THE LENGTH OF THE CALORIFIC OSCILLATIONS OF ITS MOLECULES. BY RAOUL PICTET.*

TRANSLATED BY CHIEF ENGINEER ISHERWOOD, U. S. NAVY.

If heat is admitted to be purely and simply the manifestation of the molecular forces possessed by the particles of bodies, there must necessarily also be admitted that the mechanical work transmuted into the calorific movement displaces these particles from their position of equilibrium and causes them to move in elliptical paths whose amplitude is proportional to the work transmuted.

At the absolute zero of temperature there is no oscillation of the particles and their cohesion is *maximum;* but at a certain temperature, measurable for each body, the oscillation is *maximum* and the body, disaggregating, melts, the molecules swinging sufficiently apart to lose the condition of stable equilibrium.

In this hypothesis, the absolute contact of the material particles is rendered impossible by the action of the ether. That the attraction of matter for the ether does not follow the same law as the attraction of matter for matter, is admitted; and across insensible distances the attraction of

* *Comptes Rendus*, 1879; volume 88; page 805.

matter for the ether exceeds the attraction of matter for itself.

In these conditions the *repulsive forces* vanish, and there would exist in nature only the *attractive forces.*

On the above bases let there be considered the action produced by external work done upon a body supposed to be at the absolute zero. Each particle oscillates from an exterior extreme position to another limited interior position. Evidently, the result of this molecular movement will be an augmentation of the volume of the body *pro rata* to the *mean length* of the oscillations of the elementary particles of the body.

The *coefficient of dilatation* will then be in proportion to the number of molecules contained in the body, either with the volume in which the molecules are contained, or finally with the physical forces which the calorific movement puts into action.

Now the two following postulates can be admitted:

The laws of the attraction of matter for matter are absolutely general and universal.

The phenomena of disaggregation of bodies are subject to these laws.

These being premised, and calling N the number of molecules contained in unity of length of a solid body; designating by l' and l the lengths of the oscillations corresponding to the temperatures t' and t; and letting a be the coefficient of the dilatation of the solid body; the following equation evidently results, namely:

$$\int_{l}^{l'} N\,dl = \int_{t}^{t'} a\,dt.$$

Now N is determined by the density and the atomic weight of the body.

As in one cubic metre there are $\frac{d}{p}$ particles — calling d the density and p the atomic weight—we have, in order to obtain the number of molecules N, that is to say, the

number of molecules contained in the linear unit or edge of the cube,

$$N = \sqrt[3]{\frac{d}{p}}.$$

Taking a for the dilatation measured between zero and 100° Centigrade, there is directly obtained the relation

$$l_{100} - l_0 = \frac{a}{\sqrt[3]{\frac{d}{p}}}$$

which gives the value of the augmentation of the length of calorific oscillation when the temperature increases from zero to 100°.

Now, if the attraction of matter for matter obeys a general law, each solid molecule should divide into two or more liquid molecules when the oscillations became equal to a certain *maximum*.

Two physical laws would then be confirmed, which are the inevitable consequences of these deductions, namely:

(1) *The higher the melting point of a solid, the shorter are the molecular oscillations.*

(2) *The melting points of solids correspond to the lengths of equal oscillations: the products of the lengths of the oscillations by the melting points should be a constant number for all bodies.*

These two laws are verified as closely as the experimental determinations of the different elements which enter into the foregoing equations permit.

TABLE OF THE LENGTHS OF CALORIFIC OSCILLATIONS OF SOME SOLIDS, AND OF THE PRODUCTS OF THESE LENGTHS BY THE MELTING POINTS OF THE SOLIDS IN CENTIGRADE DEGREES ABOVE THE ABSOLUTE ZERO.

Names of the Solids.	Atomic Weight. p	Density d	Values of a (Dilatation between 0° and 100°)	Lengths of Oscillation. $\frac{a}{\sqrt[3]{\frac{d}{p}}}$	Melting Points of the Solids in Centigrade Degrees above the Absolute Zero t.	$t \times \frac{a}{\sqrt[3]{\frac{d}{p}}}$
Silenium, .	39·75	4·30	0·00368	0·007725	490	3·7854
Lead, . . .	104	11·35	0·0028657	0·005382	608	3·272
Zinc, . . .	32·7	7·19	0·002942	0·004873	723	3·523
Silver, . . .	54·	10·60	0·00193	0·003077	1250	3·841
Copper, . .	31·75	8·90	0·001715	0·0026215	1323	3·468
Gold, . . .	98·	19·26	0·001466	0·0025205	1373	3·459
Iron, . . .	28·	7·79	0·0011717	0·0017805	1873	3·340
Platinum, .	198·5	21·53	0·0008642	0·001854	1973	3·658

The foregoing table contains the metals whose coefficients of dilatation are known with sufficient accuracy for the purpose of testing the truth of the laws.

The above table shows that the lengths of the oscillations are in the inverse ratio of the melting points, and that the products of these quantities are sensibly constant. The two laws above indicated are consequently correct, and temperature is really represented by the length of oscillation of the molecules of solid bodies.

Analogous equations involve the elements of volatile liquids when compared at their boiling points.

ON SOME EARLY FORMS OF ELECTRIC FURNACES.

No. 9. WATT'S ELECTRIC FURNACES.

By Prof. Edwin J. Houston.

At the meeting of the Royal Society in London, on November 19, 1807, Sir Humphrey Davy gave a description of the methods employed by him in his classic experiments on the electrical decomposition of the fixed alkalies. The paper in which this announcement was made was published in the Philosophical Transactions for 1808.

Since the electric furnaces described in this number, as well as some of the forms contained in several of the preceding numbers, are dependent for their operation on electrical principles, first discovered, or applied to such purposes by Davy, a brief prefatory account of his processes may not be without interest.

Davy was the pioneer in all electrolytic decompositions of saline salts rendered conducting by the action of heat. Solids, originally non-conductors, acquire the power of electrolytic conduction, when heated to the point of fusion.

Davy first tried to electrically decompose saturated aqueous solutions of the alkalies, but failed, and correctly ascribed the cause of such failure to the decomposition of the water.

Quoting from the Transactions of 1808, he writes:

"The presence of water appearing to prevent any decomposition, I used potash in igneous fusion. By means of a stream of oxygen gas, from a gasometer, applied to the flame of a spirit lamp, which was thrown on a platina spoon containing potash, this alkali was kept for some minutes in a strong red heat and in a state of perfect fluidity. The spoon was preserved in communication with the positive side of the battery of the power of 100 of 6 inches, highly charged; and the connection from the negative side was made by a platina wire."

By the aid of this arrangement Davy succeeded in obtaining potassium, the derivation of which from potash he showed synthetically by allowing it to be oxidized by exposure to the air.

In order to eliminate the effects of the atmosphere, Davy confined the fused potash in glass tubes, into which the decomposing current was led by platinum wire, hermetically inserted in the glass. Such a structure formed in fact a species of early electric furnace. It was not, however, practical for continous working, since the glass tube was rapidly corroded by the action of the highly heated alkali.

In 1851, Charles Watt, of England, took out letters-patent No. 13,755 of 1851, in Great Britain, for "Improvements in the decomposition of saline and other substances, and in separating their component parts, or some of them, from each other, etc., etc." In the specification of these letters-patent, Watt describes a number of applications of electricity for metallurgical operations.

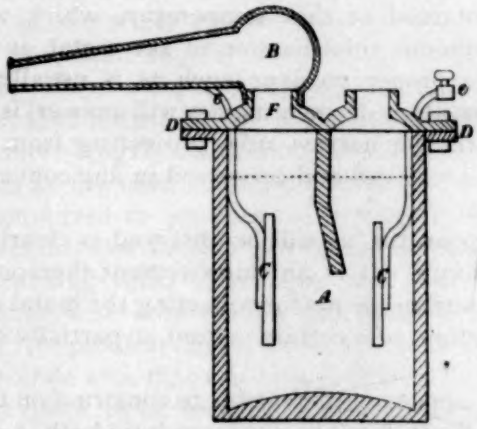
In one of these processes, he describes an apparatus suitable for the electrolytic decomposition of metallic salts of such metals as are readily volatilized at comparatively low temperatures. In order to render the salt an electrolyte, it is placed in a suitably shaped vessel provided with terminals or electrodes, and subjected to a temperature not only sufficiently high to fuse the same, but also to volatilize the metal as soon as it is separated by the action of the current.

Watt describes this form of furnace or electrolyzing cell in the specification of the above English patent. We append a quotation preferably to a condensed statement of the same, so as to avoid reading into the description the knowledge of the present day.

"The second part of my invention consists of a mode of preparing or obtaining the metals of the alkalies and alkaline earths by the united action of electricity and heat. For performing this part of my invention, by the united action of electricity and heat, I employ a vessel of the form shown in *Fig. 5*, which is made of iron, or other suitable material,

Section

FIG. 5.



capable of bearing a full red heat. In this figure, *A*, is the vessel which should be at least half an inch thick, and if made of iron, previously to its being used, should be coated over its exterior with clay or other substance to preserve it from the action of the fire; *B*, movable head for the collection of the metals; *C*, electrodes, with their attachments *e*; *D*, flanges to support the vessel upon the furnace. The covered compartment *F*, being that in which it is intended to eliminate the metals, is supplied with a carbon electrode, and the uncovered compartment is supplied with a gold electrode; but I wish it to be understood that I do not restrict myself

to the particular form of apparatus, or to the material to be used for electrodes. The vessel is filled with dry saline matter, so that when it is in a state of fusion it shall reach the dotted line; the partition keeps the eliminated substances from reacting upon each other, and also excludes the air from the compartment in which the metal is eliminated, the access of which would cause the metals to be oxidized. The vessel is placed in a furnace, where it can be subjected to the action of a full red heat, and when the saline matter is in a state of fusion, contact is made between the decomposing vessel, and should at least be equal to that which would be supplied by ten cells of Daniell's battery arranged for intensity, but, of course, this depends on the nature of the salt that is being decomposed. The fused salt is maintained at that temperature which will ensure the instantaneous volatilization of the metal, as it is eliminated, and a proper receiver (such as is usually employed for the preparation of such metals will answer) is connected air-tight with the narrow tube projecting from the head. The metal is received and preserved in any convenient fluid hydrocarbon."

Watt's apparatus, as will be observed, is clearly a modification of Davy's. It is an improvement thereon, however, in that it describes means for collecting the metal as evolved, and is, therefore, to a certain extent, a partially continuous process.

It would appear quite feasible to construct on the general line of the Watt furnace, or electrolytic bath, a continuous process for the electrical production of sodium or other volatile metal. Such a device would require the following parts, viz:

(1) A suitable electrolyzing chamber for the reception of the fused salt.

(2) Electrodes, the character of which would vary with the metal to be decomposed, though for most purposes carbon would be suitable.

(3) Hoods covering the electrolyzing chamber and placed over the negative and positive electrodes respectively, connected with suitable pipes for the collection of the volatil-

ized metal and the electro-negative constituent of the fused and electrolyzed salt. When so desired the collection of these substances may be aided by the action of a suitable pump, that maintains a partial vacuum or diminished pressure on the surface of the electrolyzing chamber.

(4) An accessory chamber containing a store of salt, fused or unfused, that may automatically, or at stated intervals, be allowed to communicate with the electrolyzing bath and so maintain the level of the fused salt therein.

(5) Suitable means for maintaining the salt to be electrolyzed in a fused state. This heat may be either of ordinary origin, or it may be electrical.

I would propose the following as a practicable plan for readily obtaining a high temperature in a limited space, by the action of electrical currents, viz: employ an inverted induction coil; send rapidly alternating currents through the primary coils of comparatively high resistance and great length, and thus induce in the secondary coils of low resistance and short length enormous currents of great heating power, such as are used in electric welding. Such currents could be employed to produce the comparatively low temperatures required in connection with the apparatus proposed above, by causing them to traverse and heat to incandescence coils of wire surrounding the space or vessel to be heated, or to produce more intense temperatures by the action of voltaic arcs that are caused to play directly on the furnace or space to be heated. They would appear to be particularly suited to such metallurgical processes where different fusions are to be effected.

The device proposed would possess the advantages of being readily obtained in a limited space, and of producing the highest temperatures possible. The ease with which ordinary smelting operations could be carried on in all locations within reach of an alternating-current circuit, even on a comparatively extended scale, is evident.

Devices for regulating the intensity of the heat so produced, by either regulating the current that passes, or the magnetic resistance of the inverted induction coil by whose agency it is produced, could readily be arranged.

In all forms of electric furnaces heretofore described, where the reduction of metallic substances is effected by the heat of the voltaic arc alone, and where electrolysis has no part in the reaction, voltaic arcs produced by the passage of rapidly alternating currents through inverted induction coils could readily be employed. Indeed it is possible, that in many cases where the action of the electricity is believed to be mainly of an electrolytic nature, experiment would show that the action is rather the chemical action of the intensely heated carbon electrodes, thus extending the field of action of heat produced by alternating current arcs.

Watt also describes in the specification of the above mentioned patent a process for the electrical separation of alloys of metals suitable for the refining of gold and silver waste.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, May 5, 1888.

THE INFLUENCE OF ALUMINIUM UPON CAST IRON.*

BY W. J. KEEP, C.E., PROF. C. F. MABERY, S.D., AND L. D. VORCE.

Aluminium is a metal obtained from its oxide alumina. It is white in color and very tenacious, and it alloys readily with iron. Cast iron ordinarily used is iron which contains all the carbon that it could absorb during its reduction in the blast furnace. This carbon, when found in chemical union with the iron, is called combined carbon. In this state it cannot be seen. It is also found mechanically mixed with the iron in the form of graphitic carbon, when it becomes visible. Other elements commonly found in cast iron are phosphorus, sulphur, manganese and silicon. The natural condition of carbon in iron is the combined state. The presence of silicon drives a portion of the carbon into the graphitic state.

*A Paper read by W. J. Keep, Detroit, Mich., at the Cleveland meeting of the American Association for the Advancement of Science.

Sulphur, manganese and phosphorus do not cause the carbon to leave its natural combined state, and if silicon be present, these elements either drive it out or overpower it. Carbon is therefore a passive element, and is made to change its form by the presence of other elements. It is this change of carbon which indicates to the eye the influence of any element upon the cast iron. Iron and combined carbon or carburetted iron is called white iron, and the grain is generally very fine, and often even, and the metal is very hard. Graphite darkens the fracture until it becomes a very dark gray, and the grain is coarse and irregular. With increase of graphite the metal becomes soft. We shall confine ourselves in this paper to the influence of aluminium upon cast iron.

Let us, for a moment, review the present knowledge on this subject. It is known that fused wrought iron, a mixture of cast iron and steel, or steel alone, either of which would make castings which would be full of blow-holes, will make solid and homogeneous castings if as small a quantity of aluminium as one-tenth of one per cent. is added just before pouring. Also that such addition causes the iron to remain fluid long enough to allow its being cast into moulds. It seems to be the general opinion that the aluminium does not remain in the metal, but that it exerts its influence between the time of its introduction and the time of its departure. This seems to be the sum total of the present information regarding the influence of aluminium upon iron.

We propose in this paper to give the results of a series of very carefully conducted tests, to further substantiate the statements just made, and to settle the question as to whether aluminium remains in the casting. Also to determine the influence of this metal upon the physical structure, and upon the composition of iron. The physical tests that we have employed are what are known as "Keep's Tests," and by them we are enabled to make apparent to the eye the influence of any element upon cast iron.

When it was understood that we were to undertake this examination, the Cowles Electric Smelting and Aluminium

Company kindly furnished us with what ferro-aluminium we needed, and Prof. C. F. Mabery and L. D. Vorce volunteered to undertake the chemical examination of the test bars. The results of these investigations will be appreciated when it is understood that we began without the least expectation of the very important results we have obtained, and that the methods for the determination of minute quantities of aluminium were so imperfect that the small quantities used in the "Mitis" process could not be determined, if they still remained in the castings.

Regarding the physical tests, we should state that we use two bases, one a white iron, with composition Si 3·86, Al 11·42, P ·263, S ·0307, Mn ·092. The other, a gray Swedish iron marked FLM, with composition Si 1·249, P ·084, S ·04, Mn ·187. The ferro-aluminium contained silicon.

The melting was done in a covered plumbago crucible, in a coke furnace driven by a blast of two and a quarter ounces. The test bars were one foot long and cast in pairs, one being half an inch square, and its mate one-tenth of an inch thick and one inch wide.

We started with thirty pounds of the base in the crucible. At the first heat there were cast four pairs of bars from the base alone, which took five pounds of metal. After allowing the remaining metal to become solid, we returned the runners of the first cast, and added four pounds of the base, and returned the crucible to the furnace. When nearly melted we added enough ferro-aluminium to bring the percentage of aluminium in the whole to where we wished it, for the second set of bars. We proceeded in like manner through the entire series of heats. To arrive at the influence of the aluminium, we made another series of heats, with the same base, with exactly the same conditions, only we did not add the aluminium.

The difference between the two series of tests gives the effect of the aluminium.

We shall consider this subject under the following heads: (1) The solidity of castings, and the prevention of blow-holes. (2) Does the aluminium remain in the iron to exert an influence when the iron is remelted? (3) The effect

of aluminium upon the grain, or the changing of the carbon from the combined to the graphitic state. (4) The taking away the tendency to chill. (5) The prevention of sand scale. (6) The effect upon hardness. (7) The resistance to a load suddenly applied, or a dead weight. (8) The resistance to a load suddenly applied, impact. (9) The elasticity. (10) Permanent set. (11) The effect on the shrinkage of the iron. (12) The fluidity of the melted metal.

(1) THE SOLIDITY OF CASTINGS, AND THE PREVENTION OF BLOW-HOLES.

All of our tests bear upon this subject, but we have made one test, using the white base iron, and one-tenth of one per cent. of aluminium. It is almost impossible to get a solid casting of the white base alone, and its resistance to weight is generally about 175 pounds for the half inch square bars, and its resistance to impact is about 100 pounds. We have obtained, however, exceptionally sound castings of this base, and we shall use the strength of such castings for comparison.

These sound castings of the white base alone resisted a weight of 379 pounds. With one-tenth of one per cent. of aluminium added, it resisted 545 pounds, a gain of 166 pounds, or about forty-four per cent., from this small addition. Measuring the resistance to impact the white alone was 289 pounds, with aluminium 254 pounds, or about six per cent. gain. The castings appear of slightly finer grain, and the character of the crystallization is somewhat different, but the secret of the strength lies in the closing of space between the grains, or, in other words, in the increased solidity of the casting. No other change is noticeable in the metal.

A graphic representation of this test is not needed.

(2) DOES THE ALUMINIUM REMAIN IN THE IRON TO EXERT AN INFLUENCE WHEN THE IRON IS REMELTED? (*Fig. 1.*)

To determine this we made a series of six heats from the white base, and added to the first heat one-fourth of one per cent. of aluminium. This amount alters the grain very perceptibly, making it whiter and finer, and removing

the tendency of the base to a slight specular appearance and giving a homogeneous fracture. It increases the strength above the base about twenty per cent. to resist weight, and for impact an increase of over seventy per cent. The next heat was a remelt of the first, with the runners of the first cast put back, and enough white base added to reduce the aluminium to two-tenths of one per cent. when the second cast was made.

Our comparison will now be made between this series and the comparison series of the base alone. Looking at the chart, we see that the effect of the aluminium in the second heat is greater than it was in the first case to which heat the aluminium was added. This is due to the increasing porosity at each heat of the base when melted alone, and to the solidity of the series with aluminium. At the third and subsequent heats the same result is apparent, the remaining aluminium causing more solid castings, though the continued additions of white iron at each heat, and the consequent lessening of aluminium, render the castings less strong at each re-melting. Yet the effect of the aluminium is so constantly apparent at each melt, as to leave no doubt as to the presence even in the sixth re-melting. The chart which we have prepared shows those effects, both as to weight and impact.

As we proceed with the description of other tests, it will be noticed that we add but a small quantity of aluminium at each heat, and depend upon the additions made at previous heats to bring up the required percentage.

The results of the tests show conclusively that the aluminium remains and exerts its influence in subsequent casts as fully as would be expected.

(3) THE EFFECT OF THE ALUMINIUM UPON THE GRAIN, OR THE CHANGING OF CARBON FROM THE COMBINED TO THE GRAPHITIC STATE.

Let us say a few words in regard to the way in which, and the reason why, carbon takes on the graphitic form. All of the carbon, both combined and graphitic, which the iron is capable of holding when solid, must be dissolved

and exist as combined carbon in the melted iron. Cast iron made in the usual way contains all of the carbon that it can hold. Very often cast iron, when melted, contains more carbon than it can hold in combination when at a lower temperature; if so, as the iron cools down, such excess of carbon will separate as graphite and rise to the surface. In any case when a melted iron contains more carbon than the iron can hold in combination when cold, all of the excess will not be able to reach the surface, though it may not be visible in the casting to the eye. The introduction of other elements into the melted metal may alter its ability to hold the carbon. Sulphur causes it to let some go, while manganese enables it to hold more carbon in solution. Silicon also somewhat diminishes the capacity of the molten metal to retain carbon while it is liquid.

Aluminium allows most of the carbon to retain its natural combined form until the metal is too thick for the separated carbon to escape, but at the instant of solidifying aluminium causes the iron to drop a portion of its carbon from the combined state. This liberated carbon takes the graphitic form, and is imprisoned in the otherwise solid iron. The advantage arising from a charge of carbon from the combined to the graphitic state at the instant of crystallization is that all the carbon thus liberated is imprisoned uniformly throughout the casting, and is not accumulated in pockets forming soft and hollow spots, as would be the case if liberated while the casting was yet fluid. Aluminium, more than any other known element, accomplished this. It not only changed white iron to gray, but seemed at once to change the whole character of the metal. The drop of carbon seems to be instantaneous, at the instant of crystallization, and for this reason the time taken in cooling has little effect. In fact, when the aluminium obtains full control of the carbon it would seem that the more sudden the cooling the more the formation of the graphite, and the thin portions of the casting are therefore as gray as the thicker portions. The powerful and positive influence of aluminium upon the carbon, and therefore upon the grain and color of the iron, is shown by an

examination of the samples. Take those made from the white iron base, with almost no silicon present. The base alone gives a white bar full of blow-holes. An addition of one-quarter of one per cent. aluminium gives us not only a perfectly homogeneous and solid casting, but the color is darker, and the grain shows that some of the carbon has taken the graphitic form. The thin casting shows this even more than the heavier bar, showing that the change occurred suddenly, and that time had but little effect. Examining such bar in turn, we see that each similar addition of aluminium produces a corresponding effect, until at the third addition, or three-fourths of one per cent., the casting is gray with no sign of white, either in the square or in the thin bar.

The set of tests with the gray iron base, containing one and one-quarter per cent. of silicon, shows that silicon and aluminium work together in the same direction, and that a slight addition of aluminium takes the white out of the casting at once, giving the same grain in a thin as in a thick casting.

This effect increases as the aluminium increases, and the indications are that at least up to four per cent., the limit of our experiments, the more aluminium, the softer and grayer the castings.

4. THE TAKING AWAY THE TENDENCY TO CHILL. (*Fig. 2.*)

If cast iron be cooled very suddenly, the carbon, which the melted metal holds in combination will not have time to separate, and will be retained in the combined state. Such castings are called chilled castings. Chill is caused by molten iron running against a body which rapidly withdraws its heat, causing it to retain its carbon in the combined form. Back from the chill, where this instantaneous cooling could not exert its full effect, a portion of the carbon takes the graphitic form. This property is made use of when it is desirable to obtain hard wearing surfaces, and in the same casting tough and soft central portions, as in car wheels. While this chilling effect is exceedingly valuable for many purposes, yet, generally speaking, the founder desires exactly the reverse.

We have said that aluminium causes the carbon to assume the graphitic form on the instant of solidifying, and therefore the sudden abstraction of heat does not imprison the combined carbon and cause chill.

This effect of aluminium is to give a uniform grain for thick and thin castings, and not allow the coldness of the mould to affect the grain.

5. THE THICKNESS OF SAND SCALE.

This is an important consideration, for the sand must be cleaned from the casting, and the surface must first be cut before the interior can be reached. To prevent the iron from burning the sand into itself, and thus forming a scale, a plumbago facing is sifted on the surface of the mould, but it is difficult for the facing to lie on the surfaces, or to resist the intense heat of the metal. When aluminium in an iron causes the dropping of the graphite from the mass of the metal, that graphite which is on the surface of the casting separates and forms a perfect plumbago facing, which opposes the sand and the heat. It will therefore be seen that in castings having sufficient aluminium to cause this separation of graphite, there will be no sand clinging to the face, and that the surface will be soft as the interior of the casting. Every iron-worker will appreciate this good effect of aluminium.

6. THE EFFECT UPON HARDNESS.

Hardness in cast iron is caused by the carburetted or white iron in masses large enough to oppose the tool. If the carburetted iron exists in minute threads stretched around atoms of graphite, a tool will easily cut it, and it will not be considered hard. This graphitic carbon, minutely dividing the mass, gives the tools of the workman a chance to cut or break the films of metal, giving what we call softness to the iron. The later the carbon is dropped the smaller will be the atoms of graphite and the closer the grain. Yet this greater subdivision will, for the reason just given, make the iron work more easily. The fineness of the grain of iron affected by aluminium causes such iron to be much more easily cut than iron of coarser grain.

The power of wrought iron and steel to resist extension is so great that where such stresses are to be resisted, decarbonized metal should be used. The resistance of any cast iron to crushing is so great that we need not consider this. The forces which cast-iron structures should be made to resist, aside from crushing, are a dead weight, or a blow applied transversely. We should therefore test cast iron with these forces.

7. RESISTANCE TO A LOAD GRADUALLY APPLIED OR A DEAD WEIGHT. (*Fig. 3.*)

If we compare the transverse breaking weights of the two series which we have been considering, number by number, we perceive that the aluminium has increased the strength to sustain a constant load. This is a very important effect, and, perhaps, comes partially from the tenacity and strength of aluminium itself, but probably more from the uniform grain of the iron.

8. RESISTANCE TO A LOAD SUDDENLY APPLIED OR IMPACT. (*Fig. 4.*)

It may be thought that the effect is substantially the same, whether the force be a constant weight or a suddenly-applied blow. We shall at a future time prove that the effects are not the same, and that an iron should be tested by a blow if it is expected to resist impact. By a comparison of the graphic representation, we see that the capacity to resist impact is increased by the addition of aluminium much more than the capacity to resist a dead weight. It will be seen at a glance that the test bars made with the white base are benefited far more than those made with the gray base. The reason for this is, that the white base alone made porous castings; at each remelt this porosity increased, due to the continuation of the heat, running the strength down to sixty-eight pounds at the fifth heat. The first and each subsequent addition of aluminium caused the castings to be perfectly sound, and the infinitesimal atoms of graphite deposited throughout the metal removed the rigidity and brittleness of the initial metal.

FIG. 1.

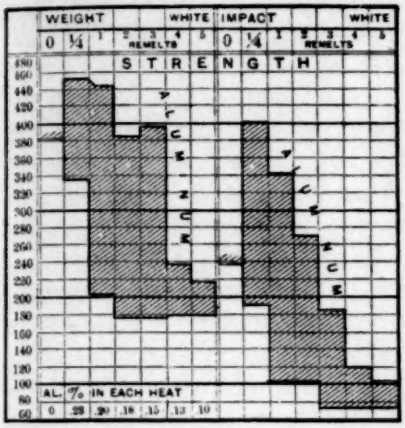


FIG. 2.

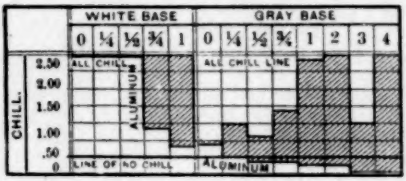


FIG. 5.

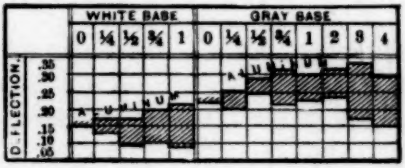


FIG. 3.

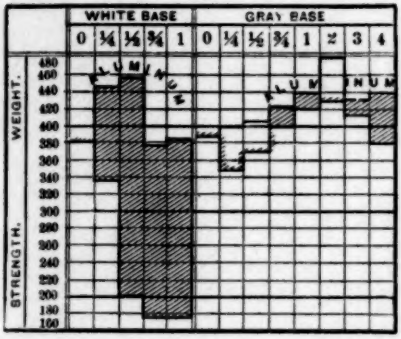


FIG. 6.

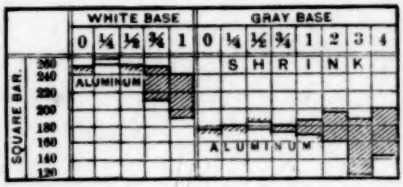


FIG. 4.

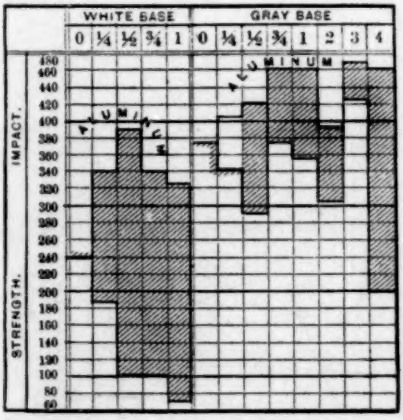


FIG. 7.

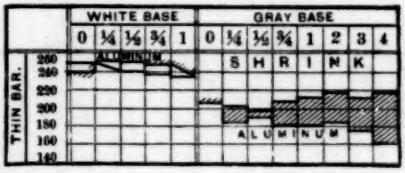
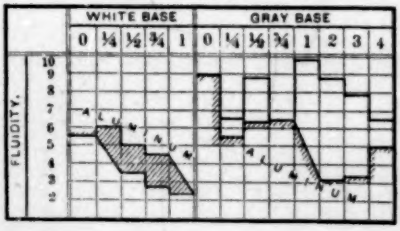


FIG. 8.



GRAPHIC ILLUSTRATION OF THE INFLUENCE OF ALUMINIUM ON CAST IRON.

The gray iron base contained enough silicon to accomplish all this, and the only effect on strength that the action of the aluminium on carbon could have, would be to increase the fineness of the grain, unless the toughness of the aluminium itself could give strength to the casting, though the aluminium, no doubt, removed any slight blow-holes that existed in the initial gray metal. This leads us to notice that each addition of aluminium increases the strength over that of the initial metal. We must expect that after we have added enough aluminium to cause a solid casting and to remove the brittleness which the dividing up of the mass by the atoms of graphite accomplishes, any further additions of aluminium, and consequent increase of graphite (which has no strength of itself) must weaken the casting.

9. ELASTICITY. (*Fig. 5.*)

The compactness and closeness of the grain of cast iron, when aluminium was the agent by which the graphite was precipitated, and the fine attenuation of the veins of iron and combined carbon, cause the metal to be very elastic, and, as we have seen, not so brittle as without aluminium.

10. PERMANENT SET.

This is caused by the compression of the graphite within the framework of iron and combined carbon. When this compression of graphitic carbon is produced by transverse bending the framework of the metal also takes on a permanent form, which cannot be altered, except by a greater force than was before applied. The fineness and compactness of iron alloyed with aluminium gives less permanent set than iron equally as soft when such softness is produced by silicon.

11. THE EFFECT ON THE SHRINKAGE OF THE IRON.

The more suddenly and completely the carbon is changed from combined to graphitic at the instant of the crystallization, the more space will the casting occupy. When the casting is cold it will, therefore, have contracted less than if more carbon had remained combined. White iron, having

most of its carbon in the combined state, shrinks from one-fourth to one-third of an inch in each foot. Gray iron sometimes shrinks as little as one-tenth of an inch to each linear foot. As the combined is the natural state for the carbon, we may say that this maximum shrinkage is the natural shrinkage for cast iron having its carbon combined. We can, therefore, say that aluminium takes out or reduces shrinkage. This is a very great advantage, as shrinkage, when a sufficient quantity is added, requires great skill in the preparation of patterns to prevent warping and cracking and violent internal strains within the castings. The lessening of shrinkage avoids these evils, and is therefore a great gain.

Looking at chart (*Fig. 6*), for shrinkage, we see the most conclusive proof of our explanation of the way in which shrinkage is lessened. With both the white and the gray bases, during the first two additions the shrinkage of the square bar is slightly increased. The influence of the aluminium thus far has been in the direction of elimination of blow-holes and causing an even distribution of the dark and light grains. At the third addition, however, when the amount reached three-fourths of one per cent., the effect was appreciably felt upon the carbon, as seen by the color, and as we should expect, from the deposition of this large bulk of graphite, the casting does not shrink as much, and, each addition of aluminium, increasing this bulk of graphite, decreases the shrinkage.

The effect upon the grain and color of the thin bars of the series (*Fig. 7*) is very remarkable, showing that the aluminium has changed enough carbon to graphite to produce a dark even-grained casting. The effect upon the shrinkage of thin bars is as we should expect, and is more marked even than in the square bars. The shrinkage in thin bars of the white series shows a constant decrease as the aluminium increases, but in the series for comparison, the shrinkage dropped still more rapidly. If a new crucible were used in commencing this comparison series, enough silicon might have been absorbed to produce this effect. This leads us to remark that on account of the variations of

conditions in any series of tests, that cannot be foreseen, we must avoid drawing any but general conclusions, and these should be based upon a large number of experiments.

12. THE FLUIDITY OF THE MELTED METAL. (*Fig. 8.*)

Our tests of fluidity are correct as far as each individual heat is concerned, but variation may be due to the heat of the metal of that particular cast when poured. Viewed in a general way, the indications are that with the white base, with almost no silicon, the aluminium has increased the fluidity; judging from the series with the gray base, we would say that combined with silicon, aluminium reduced the fluidity, but later tests show that the aluminium, to a very marked degree, increases the fluidity.

Our remarks in connection with shrinkage show that a sharp casting is produced by the instantaneous dropping of graphite when crystallization takes place, and that if the iron is fluid enough to fill the mould any extra fluidity causes the iron in shrinking to draw away from the mould. Again, the per centage of aluminium necessary to bring about these desirable results will be too small to have much effect upon the fluidity of the metal.

The fact of the iron giving sharper and more perfect castings, caused by the deposition of graphite at the instant of solidification, might cause the iron to be pronounced more fluid, if judged by the appearance of the castings. No doubt the presence of varying quantities of manganese, sulphur, phosphorus and silicon in the cast iron used would modify the influence of aluminium, and until this is understood it may require considerable experiment to determine the amount of aluminium required or how it shall be introduced.

This hurried presentation of the remarkable effects of aluminium upon cast iron will give an idea of the great benefit which is now promised to the iron founder by the rapidly falling price of aluminium as cheapened by the electric furnace.

GENERAL THEORY OF JOINTED BOW GIRDERS.

By E. A. Werner, C.E.

(*Continued from Vol. cxxvi, page 63.*)

EXAMPLE.

CIRCULAR ARCH.

As an example, I have calculated in the following a stiffened truss, with a *circular* line of thrust, of 150′ feet span, divided into 10 panels of 15 feet each, and 50 feet depth of bow, or height of top joint above the abutment joints.

I will state here that I selected the example on purpose, from the point of view only, to introduce the reader as much as possible into the novelties of the bow structures and not with the intention to give a standard model truss.

The truss is supposed to carry one track of a railroad, the road lying 25 feet above the abutments.

It is furthermore supposed that the *upper chord takes up completely and fully* the thrust of the bow.

As loads are assumed:

Own weight (iron and track), . . .	= 18,000 pounds.
Moving load, 3,000 pounds p. l. f., .	= 45,000 "
	63,000 pounds per

panel point.

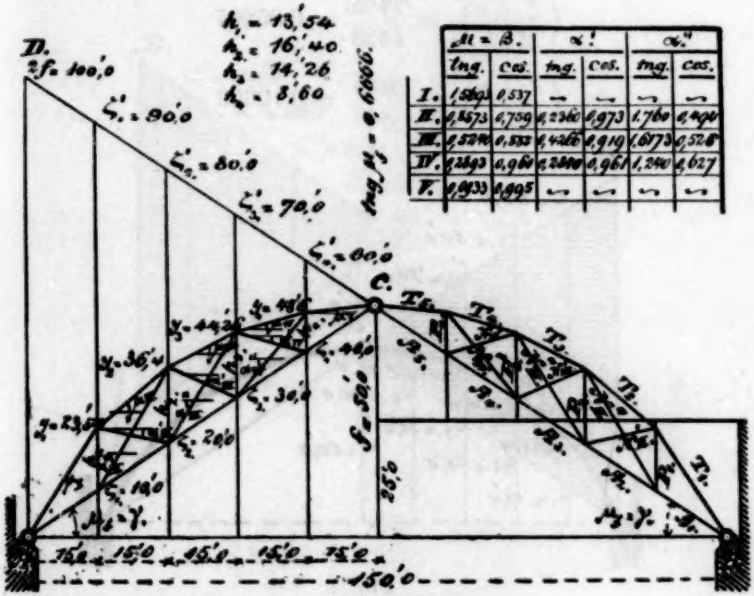
The loads—own weight and moving loads—are considered as taken up *both* in the same panel points. If it should be preferred to distribute the own weight over the panel points of both chords, P only would change, and the necessary correction can be easily made.

The calculation is made so, as if every panel point always were completely loaded. In fact, this is not the case, as the panel points on the beginning and the end of the loaded parts will not be loaded

fully. This way of calculating gives generally somewhat greater strains, but it shows exactly the division lines. Still, in a concrete example, it will always be good to calculate the values of $G_1\ G_2\ G_3$, according to the special specifications.

DATA OF CALCULATION.

The following diagram gives all the data necessary for calculation:



	$\alpha = \beta$.		α^1		α^4	
	tng.	cos.	tng.	cos.	tng.	cos.
I.	1,5893	0,537	—	—	—	—
II.	0,8573	0,759	0,2360	0,973	1,760	0,490
III.	0,5246	0,883	0,4260	0,919	1,0773	0,678
IV.	0,2493	0,969	0,2880	0,961	1,240	0,627
V.	0,0933	0,995	—	—	—	—

FIG. 1.

COEFFICIENTS.

$$\left(\frac{M}{h}\right)$$

$$\left(\frac{\zeta' - y}{2fh}\right)_1 = \frac{66{\cdot}46}{1354} = 0{\cdot}04908$$

$$\left(\frac{\zeta' - y}{2fh}\right)_2 = \frac{43{\cdot}6}{1640} = 0{\cdot}02659$$

$$\left(\frac{\zeta' - y}{2fh}\right)_3 = \frac{25{\cdot}74}{1426} = 0{\cdot}01805$$

$$\left(\frac{\zeta' - y}{2fh}\right)_4 = \frac{11{\cdot}40}{860} = 0{\cdot}01325$$

$$\left(\frac{\zeta + y}{2fh}\right)_1 = \frac{33{\cdot}54}{1354} = 0{\cdot}02477$$

$$\left(\frac{\zeta + y}{2fh}\right)_2 = \frac{56{\cdot}4}{1640} = 0{\cdot}03439$$

$$\left(\frac{\zeta + y}{2fh}\right)_3 = \frac{74{\cdot}26}{1426} = 0{\cdot}05207$$

$$\left(\frac{\zeta + y}{2fh}\right)_4 = \frac{88{\cdot}6}{860} = 0{\cdot}10302$$

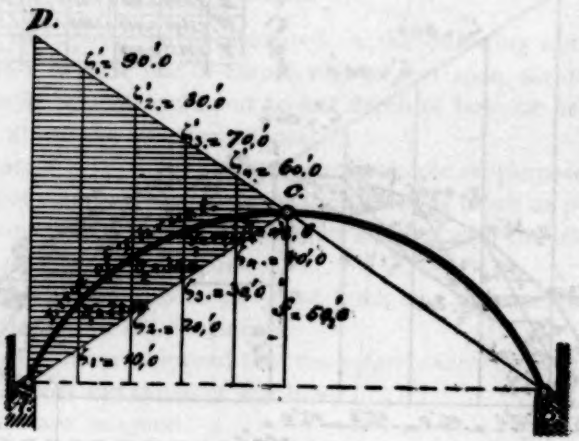


FIG. 2.

$$\left(\frac{\zeta - y}{2fh}\right)_1 = -\frac{13{\cdot}54}{1354} = -0{\cdot}01$$

$$\left(\frac{\zeta - y}{2fh}\right)_2 = -\frac{16{\cdot}4}{1640} = -0{\cdot}01$$

$$\left(\frac{\zeta - y}{2fh}\right)_3 = -\frac{14{\cdot}26}{1426} = -0{\cdot}01$$

$$\left(\frac{\zeta - y}{2fh}\right)_4 = -\frac{8{\cdot}6}{860} = -0{\cdot}01$$

$$\left(\frac{x}{h}\right)_1 = \frac{15}{1354} = 1{\cdot}10783$$

$$\left(\frac{x}{h}\right)_2 = \frac{30}{1640} = 1{\cdot}82927$$

$$\left(\frac{x}{h}\right)_3 = \frac{45}{1426} = 3{\cdot}15568$$

$$\left(\frac{x}{h}\right)_4 = \frac{60}{860} = 6{\cdot}97674$$

U.

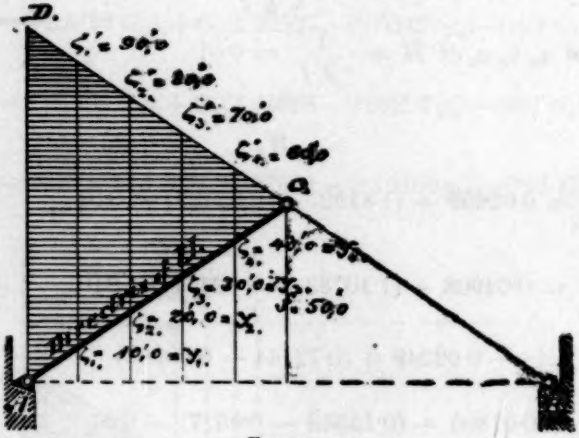


Fig. 3.

$$\left(\frac{\zeta' - y}{2\,f\,h}\right)_1 = \frac{80}{1354} = 0{\cdot}05908$$

$$\left(\frac{\zeta' - y}{2\,f\,h}\right)_2 = \frac{60}{1640} = 0{\cdot}03659$$

$$\left(\frac{\zeta' - y}{2\,f\,h}\right)_3 = \frac{40}{1426} = 0{\cdot}02805$$

$$\left(\frac{\zeta' - y}{2\,f\,h}\right)_4 = \frac{20}{860} = 0{\cdot}02305$$

$$y = \zeta$$

$$\left(\frac{\zeta + y}{2\,f\,h}\right)_1 = \frac{20}{1354} = 0{\cdot}01477$$

$$\left(\frac{\zeta + y}{2\,f\,h}\right)_2 = \frac{40}{1640} = 0{\cdot}02439$$

$$\left(\frac{\zeta + y}{2\,f\,h}\right)_3 = \frac{60}{1426} = 0{\cdot}04207$$

$$\left(\frac{\zeta + y}{2\,f\,h}\right)_4 = \frac{80}{860} = 0{\cdot}09302$$

$\left(\frac{\zeta - y}{2\,f\,h}\right)$ is equal to zero.

Check. The coefficients of $\left(\frac{M}{h}\right)$ and U are different by the value of $a_h\ b_h\ c_h$ of $H = \frac{1}{2\,f} = 0{\cdot}01$

W.

$$\left(\frac{M}{h}\right)_2 = 0\,02659 + (1{\cdot}82927 - 0{\cdot}03439) - 0{\cdot}01$$

$$\left(\frac{M}{h}\right)_1 = 0{\cdot}04908 + (1{\cdot}10783 - 0{\cdot}02477) - 0{\cdot}01$$

$$-\,0\,02249 + (0{\cdot}72144 - 0\,00962) \quad = W_{II}$$

$$\left(\frac{M}{h}\right)_3 = 0{\cdot}01805 + (0{\cdot}15568 - 0{\cdot}0527) - 0{\cdot}01$$

$$\left(\frac{M}{h}\right)_2 = 0{\cdot}02659 + (1{\cdot}8292 - 0{\cdot}03439) - 0{\cdot}01$$

$$-\,0{\cdot}00854 + (1{\cdot}32641 - 0{\cdot}01768) \quad = W_{III}$$

$$\left(\frac{M}{h}\right)_4 = 0{\cdot}02325 + (6{\cdot}97674 - 0{\cdot}10302) - 0{\cdot}01$$

$$\left(\frac{M}{h}\right)_3 = 0{\cdot}02805 + (1{\cdot}35568 - 0{\cdot}05207) - 0{\cdot}01$$

$$-\,0{\cdot}00480 + (3{\cdot}82106 - 0{\cdot}05095) \quad = W_{IV}$$

Check. The same values of H are obtained in using either $\left(\frac{M}{h}\right)$ or U.

GENERAL EQUATIONS OF $\left(\frac{M}{h}\right)$, U, W AND MAXIMAL AND MINIMAL VALUES OF THESE EXPRESSIONS.

$$\left(\frac{M}{h}\right)$$

$$\left(\frac{M}{h}\right)_1 = 0{\cdot}04908\, G_1 g_1 + G_2(1{\cdot}10783 - 0{\cdot}02477\, g_2) - 0{\cdot}01\, G_3(l - g_3)$$

$$\left(\frac{M}{h}\right)_2 = 0{\cdot}02659\, G_1 g_1 + G_2(1{\cdot}82927 - 0{\cdot}03439\, g_2) - 0{\cdot}01\, G_3(l - g_3)$$

$$\left(\frac{M}{h}\right)_3 = 0{\cdot}01805\, G_1 g_1 + G_2(3{\cdot}15568 - 0{\cdot}05207\, g_2) - 0{\cdot}01\, G_3(l - g_3)$$

$$\left(\frac{M}{h}\right)_4 = 0{\cdot}01325\, G_1 g_1 + G_2(6{\cdot}97674 - 0{\cdot}10302\, g_2) - 0{\cdot}01\, G_3(l - g_3)$$

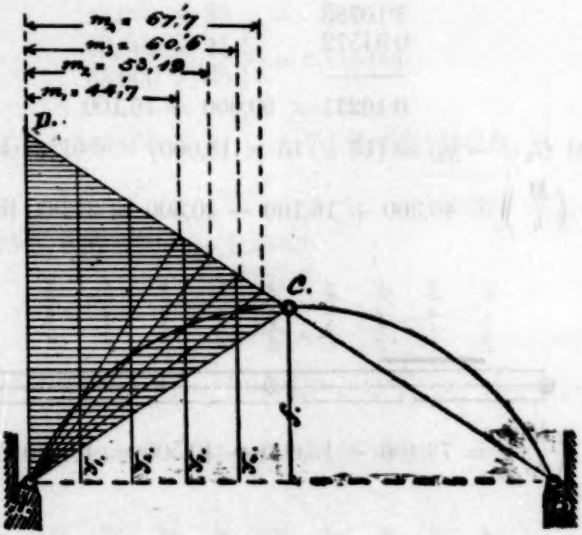


FIG. 4.

Fig. 4 gives graphically the maximum line of G_2. The same values are found from $b = o$.

The positions of the loads corresponding to the maximal and minimal values of $\left(\frac{M}{h}\right)$ and their numeric values are thus:

MAXIMA.

$0{\cdot}04908\ G_1 g_1 = 0{\cdot}04908\ (63{,}000 \times 15) = 46{,}300$

$63{,}000 \times 30 = 1{,}890{,}000$

$18{,}000 \times 45$
$18{,}000 \times 60$ $\Big\} = 1{,}890{,}000$

$G_2 = 99{,}000 \qquad 3{,}780{,}000\ (\ 99{,}000$

$38{\cdot}1818 = g_2$

$38{\cdot}1818 \times 0{\cdot}02477 = 0{\cdot}94572$

$1{\cdot}10783$

$0{\cdot}94572$

$0{\cdot}16211 \times 99{,}000 = 16{,}100$

$0{\cdot}01\ G_3 (l - g_3) = (15 \times 15 \times 18{,}000) \times 0{\cdot}01 = 40{,}500$

$$\left(\frac{M}{h}\right)_1 = 46{,}300 + 16{,}100 - 40{,}500 = 21{,}900 \text{ lbs.}$$

$$\left(\frac{M}{h}\right)_2 = 73{,}400 + 13{,}600 - 40{,}500 = 48{,}500 \text{ lbs.}$$

$$\left(\frac{M}{h}\right)_3 = 102{,}000 + 2{,}000 - 40{,}500 = 63{,}800 \text{ lbs.}$$

$$\left(\frac{M}{h}\right)_4 = 125{,}200 - 40{,}500 = 84{,}700 \text{ lbs.}$$

MINIMA.

$$0{\cdot}04908\ G_1 g_1 = (18{,}000 \times 15) \times 0{\cdot}04908 = 13{,}200$$

$$\left.\begin{matrix} 18{,}000 \times 30 \\ 63{,}000 \times 45 \\ 63{,}000 \times 60 \end{matrix}\right\} = 6{,}615{,}000$$

$$G_2 = 144{,}000 \qquad 7{,}155{,}000 (144{,}000$$

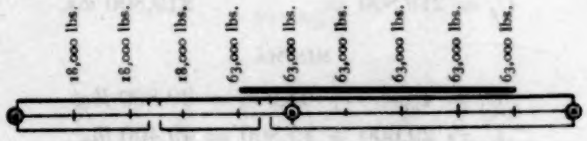
$$49{\cdot}6875 = g_2$$

$$-49{\cdot}6875 \times 0{\cdot}02477 = -1{\cdot}23076$$
$$1{\cdot}10783$$

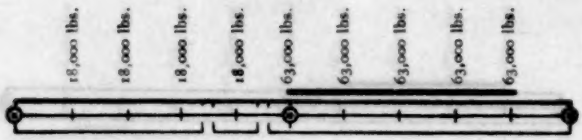
$$-0{\cdot}12293 \times 144{,}000 = -17{,}600$$

$$G_3 (l - g_3) \times 0{\cdot}01 = 0{\cdot}01\ (15 \times 15 \times 63) = 141{,}800$$

$$\left(\frac{M}{h}\right)_1 = +13{,}200 - 17{,}600 - 141{,}800 = -146{,}200 \text{ lbs.}$$



$$\left(\frac{M}{h}\right)_2 = +21{,}600 - 9{,}800 - 141{,}800 = -130{,}000 \text{ lbs.}$$



$$\left(\frac{M}{h}\right)_3 = + 29{,}200 + 600 - 141{,}800 = - 112{,}000 \text{ lbs.}$$

$$\left(\frac{M}{h}\right)_4 = + 35{,}800 - 141{,}800 = - 106{,}000 \text{ lbs.}$$

U

$$U_1 = 0{\cdot}05908\ G_1 g_1 + G_2\,(1{\cdot}10783 - 0{\cdot}01477\ g_2)$$
$$U_2 = 0{\cdot}03659\ G_1 g_1 + G_2\,(1{\cdot}82927 - 0{\cdot}02439\ g_2)$$
$$U_3 = 0{\cdot}02805\ G_1 g_1 + G_2\,(3{\cdot}15568 - 0{\cdot}04207\ g_2)$$
$$U_4 = 0{\cdot}02325\ G_1 g_1 + G_2\,(6{\cdot}97674 - 0{\cdot}09302\ g_2)$$

The maximal and minimal values are reached with full loaded and empty girder, the line $A\ C$ being directrix of U.

The divisions of $G_1\ G_2\ G_3$ in U correspond to the divisions of $\left(\frac{M}{h}\right)$

MAXIMA.

$$U_1 = 55{,}800 + 83{,}600 = 139{,}600\ lbs.$$
$$U_2 = 103{,}800 + 69{,}100 = 172{,}900\ lbs.$$
$$U_3 = 159{,}000 + 39{,}800 = 198{,}800\ lbs.$$
$$U_4 = 219{,}800 = 219{,}800\ lbs.$$

MINIMA.

$$U_1 = 15{,}900 + 23{,}900 = 39{,}800\ lbs.$$
$$U_2 = 29{,}600 + 19{,}800 = 49{,}400\ lbs.$$
$$U_3 = 45{,}400 + 11{,}400 = 56{,}800\ lbs.$$
$$U_4 = 62{,}800 = 62{,}800\ lbs.$$

W

$$W_{II} = -0{\cdot}02249\ G_1 g_1 + G_2 (0{\cdot}72144 - 0{\cdot}00962\ g_2)$$

$$w_2 = 75{\cdot}1 \ldots . \ ft.$$

$$W_{III} = -0{\cdot}00854\ G_1 g_1 + G_2 (1{\cdot}32641 - 0{\cdot}01768\ g_2)$$

$$w_3 = 75{\cdot}1 \ldots . \ ft.$$

$$W_{IV} = -0{\cdot}00480\ G_1 g_1 + G_2 (3{\cdot}82106 - 0{\cdot}05095\ g_2)$$

$$w_4 = 75{\cdot}1 \ldots . \ ft.$$

MAXIMA.

$W_{II} = -6{,}100 + 54{,}500 = +48{,}400$ *lbs.*

$W_{III} = -6{,}900 + 50{,}200 = +43{,}300$ *lbs.*

$W_{IV} = -7{,}800 + 48{,}100 = +40{,}300$ *lbs.*

MINIMA.

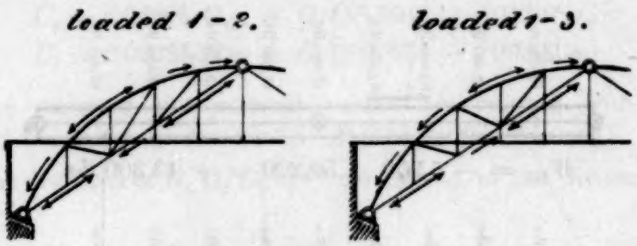
$W_{II} = -21{,}300 + 15{,}600 = -5{,}700$ *lbs.*

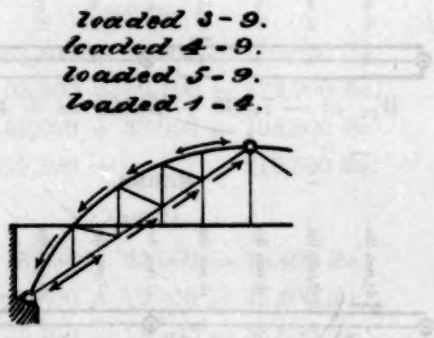
$$W_{III} = -\ 24{,}200 + 14{,}300 = -\ 9{,}900\ lbs.$$

$$W_{IV} = -\ 13{,}400\ lbs.$$

STRAINS A OF THE LOWER CHORD.

The course of the ties corresponding to the positions of the loads inducing the maximal and minimal values of $\left(\frac{M}{h}\right)$ are:





Hence the numeric values of A.

MAXIMA.

$$A_1 = A_2 = \frac{219{,}000}{0{\cdot}832} = + 27{,}000 \text{ lbs.}$$

$$A_3 = \frac{48{,}500}{0{\cdot}832} = + 59{,}000 \text{ lbs.}$$

$$A_4 = \frac{63{,}800}{0{\cdot}832} = + 77{,}000 \text{ lbs.}$$

$$A_5 = \frac{84{,}700}{0{\cdot}832} = + 102{,}000 \text{ lbs.}$$

MINIMA.

$$A_1 = A_2 = - \frac{146{,}200}{0{\cdot}832} = - 176{,}000 \text{ lbs.}$$

$$A_3 = - \frac{130{,}000}{0.832} = - 157{,}000 \text{ lbs.}$$

$$A_4 = - \frac{182{,}000}{0{\cdot}832} = - 135{,}000 \text{ lbs.}$$

$$A_5 = - \frac{106{,}000}{0{\cdot}832} = - 128{,}000 \text{ lbs.}$$

(*To be continued.*)

CORRESPONDENCE.

NATIONAL PUBLIC WORKS.

To the Committee on Publications of the FRANKLIN INSTITUTE.

GENTLEMEN:—My attention has been called to the remarks of H. W. S., in your August number, upon "The Reorganization of Public Civil Works." A different point of view is so well presented by H. in the same number, that extended comment is not required. It is easy to infer that H. W. S. may be a naval graduate, possibly of the engineering course, and that a kindred military spirit makes him more captious in regard to the civilian effort than well fits a disinterested observer. The few shrunken kernels in this peck of chaff may mislead the unwary, and therefore call for attention.

It is admitted that the Council of Engineering Societies represents the views of the civil engineering profession. No additional comment is called for.

It is possible that the scheme may sometime work as suggested by the A. B. C. illustration. Such a possibility involves a combination of two or three improbabilities, which H. W. S. is doubtless sufficient mathematician to know is a vanishing quantity. It is likely that in an organization, essentially selective in all grades, such practices will be more infrequent than under some present systems, where the clerk of the superior officer, as a technical adviser, outranks the junior personnel of the service. The illustration illustrates too much.

The publications of the Council nowhere imply that the chief of this bureau is by evolution ultimately to become the chief of a department. They expressly disclaim "an expanding organization," but advocate in time an aggregation of all the kindred bureaus. It is admitted that the chief of the bureau should be technically proficient. What the chief of the department should be is not now germane, though it may be observed that if he combines technical proficiency with executive ability, it need not be an occasion for lamentation.

The proposition to transfer one-half the Army corps to the Corps of Civil Engineers, simply recognizes that in installing the new establishment the past experience should be utilized so far as possible without impairing the military service. As the bill requires men of experience, no doubt a large proportion of the civil assistants will also enter the new establishment. This simply gives competent experience recognition beyond the mere school training of youth, and has no reference to place or manner of education.

There are sound reasons for Government education for the military service. There are sound public reasons for not extending this education to civil branches with a view to a monopoly in the civil service. This is too generally recognized for discussion. If the educational facilities outside of West Point and Annapolis are insufficient for civil requirements, doubtless they will be improved as the demand for a better article is appreciated through the civil competition of the military graduates.

The contention for the superiority of West Point education for civil pursuits has been so long abandoned that its re-assertion is decidedly refreshing. Some schools of engineering are nearly as old as West Point. The Government, in a spirit of philanthropy, has allowed graduates of the military and naval academies to go out as enlightened teachers of what it is wise to know. Surely some of these should teach as well as they have been taught, and quickly remedy the great deficiency.

Is there a presiding genius which selects for the military schools the choice brains of our land? Are there peculiar cogs in the educational machine which make them abler than able men from other schools? Are eminent educators all wrong, and the educational experience of generations at fault? Why is not the educational machine everywhere framed on these models? Is it because the admiration for the system, generically applied, is confined to the alumni of our military schools?

What constitutes an education is too large a question for present discussion. If achievements be the test, civil engineers will abide the issue. We may be sure that those who are familiar with "the quality of work done at different institutions" will never be guilty of the rash assertions of H. W. S., and he may be safely left to the tender mercy of the professors.

A provision allowing the employment of outside experts in any organization, is wise. It has happened that inventions and applications of great merit—even in arms, armament, marine engineering, etc., for the navy—have been made by men outside the ranks, and it will doubtless occur again. Such efforts are to be encouraged by provisions of law. Possibly another Eads may arise, or perhaps an Ericsson.

What the next generation may conclude is difficult to foresee. It is our duty to remedy the admitted evils of the present, and not be content on the theory that they cannot be removed because human nature is totally depraved. Experience will doubtless suggest material changes in the future, and it may be feasible still further and wisely to liberalize the service. Progress will have no debt to pay to pessimistic teachings.

What H. W. S. means to convey by comparing the pay schedule with that of "army officers of least rank allowed to do the work," is not evident. Why not compare with those of higher rank, who may do the work, if he studies the register closely, and add to their pay, fuel, forage and perquisites, and the annuity which the money invested in their education represents to the Government?

It is easy to suppose that provisions of law will be construed perversely, but is it not a fairer assumption that self-interest, if no nobler motive, will construe them in harmony with the public interests. There are possibilities and possibilities, but are they probabilities? For instance, the present service in its civil duties is without special provision of law, and we could suppose all possible evils to exist. It should be conceded that regulative provisions will not make the system of examination and promotion worse. They will certainly be needed for such a class of men as H. W. S. supposes will compose this corps.

Finally, it is admitted that improvements in the service can be made and are desirable. In all the morass of captious criticism of the Cullom-Breckinridge bill, up to this time, there has not appeared a single suggestion that could be doubled up with another, or a single body of thought outlining anything essentially different. The trouble does not seem to lie in the bill, but in mental dyspepsia occasioned by deficient digestive organs, developed perhaps on prepared food. L. E. C.

IMPROVEMENT OF SABINE PASS.

To the Committee on Publications of the FRANKLIN INSTITUTE.

GENTLEMEN:—In the Sabine Pass controversy, Prof. Haupt finds himself unable to understand the sophistry which would object to his use of the verb to build and not to that of the Board of Engineers, which Board said that the western jetty should be *built first* and its effect observed. From my point of view the sophistry resides entirely in arguing the uses to be the same, and in stating that the work was conducted according to this view of the Board, thus laying the basis for the charge. It was not so conducted, but on my recommendation that feature was changed and work on the east jetty commenced.

In the paragraph (2) on page 141 of your August number, Prof. Haupt confounds the "shoal opposite the Clifton" with the "sand area" referred to in Mr. Raymond's report, and in the paragraph quoted therefrom in my letter at the foot of page 138 and in the paragraph at the head of page 139. They are entirely different. As this fact makes it needful that that paragraph (2) should be entirely re-written, comment upon it is impracticable. The "sand area" had the following limits: It was entirely on the outer slope of the bar; its inshore limit was in a depth of 6·5 feet almost uniformly, while its seaward edge was nearly coincident with the nine foot curve; its western end was 400 feet west of the line of the jetty and from this extremity the "sand area" extended easterly 6,500 feet. Exterior to these limits sand is not found. It thus lay upon both sides of the line of deepest water from the Pass and extended as near as may be an equal distance east and west of that line, and its width diminished as it extended eastwardly until it entirely disappeared. Sand at an earlier date was found inward of this area, upon the surface of the bar, and at the later date of the survey had disappeared therefrom and there is no sand to the eastward of this area for miles.

No one will quarrel with Prof. Haupt if he still thinks that Mr. Raymond's opinion was a dubious one and that the sand came from the eastward.

Prof. Haupt regards the deepening of three to four feet along the edges of the jetty as irrelevant when he had previously constructed a ramp over the line of one of these deepenings, up which ramp sand rolled over the jetty.

Allow me the opportunity to correct an error in my letter in the August number. Of the observations made on the jetty to determine the direction of the cross currents, there was one exception to the general rule that the direction of these currents was eastward or westward according to the direction of

the wind; this exception was found inside the "Clifton" and at a distance from the shore end of the jetty of a little more than one-fourth the distance to the "Clifton." Here, with the wind east, the current was inward across the jetty, setting nearly north—the tide falling.

Very respectfully, THOMAS TURTLE,
Captain of Engineers.

WASHINGTON, D. C., August 15, 1888.

BOOK NOTICES.

NOTES ON THE COMPRESSIVE RESISTANCE OF FREESTONE, BRICK PIERS, HYDRAULIC CEMENTS, MORTARS AND CONCRETES. By Q. A. Gillmore, Ph.D. New York: John Wiley & Sons. 1888.

The evil that men do no doubt often survives them; but that all of the good is not invariably interred with their bones, this latest work of General Gillmore bears evidence.

There is "a long felt want" which this volume (while it can hardly be said to fill it, and by no means claims to do so) at least recognizes, and does much toward satisfying. We refer to the dissatisfaction which engineers have felt with regard to the published tables of strengths of materials, based chiefly upon experiments with small specimens, carefully prepared, and tested under conditions which rarely if ever occur in practice.

While the present series of experiments can scarcely be said to give us definite and generally applicable laws for deducing the practical working strength of larger pieces from these tabular results; yet, dealing with large specimens, it renders important service, not only by confirming the suspicions which have been entertained, but by indicating some of the causes which may lead to the observed discrepancies.

As the author remarks: "It was not the intention to decide upon the relative merits of the several kinds of materials employed, but to obtain further information regarding the behavior under compressive stress of both natural and artificial stone in various gradations of size.

The experiments recorded were made with the Emery testing machine, at the Watertown Arsenal, Mass., capable of exerting a maximum pressure of 800,000 pounds, and embraced specimens of Haverstraw freestone, neat Dyckerhoff Portland cement, mortars and concretes of Newark Company's Rosendale, Norton's and National Portland cements, and piers of brickwork in Rosendale cement.

Most of the experiments were made with cubes, from one to twelve inches on a side in freestone and neat cement, and from two to sixteen inches on a side in the mortars and concretes. The brick piers were twelve inches square by sixteen inches high.

The specimens of neat cement, mortar and concrete, after being taken from the moulds, were kept buried in sand for periods varying from about two to four years or until shortly before testing.

Tests were also made of prisms of freestone and of neat cement four inches and eight inches square, and of various heights less than the sides. A dry-jointed pier of three twelve-inch cubes of freestone, and three piers of twelve-inch square slabs of neat cement were also broken.

Unfortunately (other things being equal), the larger the specimens, the smaller must be their number; and the greater the diversity of sizes the fewer tests can there be of each size. And the materials here treated of, subject as they are to unknown irregularities of structure, affecting to a great but indeterminable extent their behavior under stress, are the very ones for which a great number of experiments is particularly desirable. Hence, there is, after all, a sense of incompleteness in the results and of uncertainty in the conclusions arrived at; a defect arising unavoidably from the nature of the case, and in spite of very evident and conscientious care and industry in obtaining, observing, recording and presenting the results and in reasoning from them. This defect is freely admitted by the author in such sentences as this, which may be regarded as in some sense typical of many of the results attained:

"With respect to resilience at the elastic limit, the National Portland cement cubes are decidedly superior to those of Norton cement; but the C mortars possess somewhat more resilience than the C concretes, while with the Norton cement the reverse is the case. It is possible that if more samples had been available these relations might have been changed."

Notwithstanding this, the care taken in measuring the compressions of the specimens, by means of a caliper reading to thousandths of an inch, has enabled the author to prepare a very interesting series of diagrams, which, while of course presenting different forms for the several materials operated upon, show for a given material a uniformity hardly to be expected in view of the irregularities of structure already referred to.

In addition to the results referring especially to the several materials tested, the following conclusions of general interest were reached:

From previous experiments upon cubes of Berea stone measuring from one-quarter inch to four inches on a side, the author had constructed the following formula for the strength of cubes of different sizes and of a given material:

$$\left.\begin{matrix}\text{Breaking load of a given cube}\\ \text{in pounds per square inch}\end{matrix}\right\} = \begin{matrix}\text{Breaking load of a}\\ \text{1 inch cube in pounds}\end{matrix} \times \left(\begin{matrix}\text{Edge of given}\\ \text{cube in inches}\end{matrix}\right)^{0.333}$$

The more recent experiments here described failed to confirm the formula, the larger cubes generally giving way under less loads than it would have required. This failure is quite plausibly explained as being probably due to greater want of homogeneity in the larger specimens as compared with the smaller cubes, in which "the soundest pieces are necessarily selected," whereas "the difficulty of close examination and proper selection, and the probability that the specimen contains unsound parts, increase with the size of the cubes." It is quite possible, as the author suggests, "that the law, perhaps more or less modified, would be corroborated if it were possible to provide a series of varying sizes, each of which was truly homogeneous throughout." But, even so, the impossibility of securing such homogeneity

in practice, deprives the formula of utility as a working rule, and renders it simply an interesting scientific discovery, at least until we learn to make useful practical deductions from it. But the experiments are valuable as showing the danger of applying to stone of working sizes the published figures based generally upon experiments with small specimens, for these last were found to sustain generally a very much greater pressure than the larger cubes. A comprehensive series of tests upon the crushing strengths of materials in large masses would go a long way toward reducing the "factor of ignorance," which must in the meantime be employed.

The experiments upon prisms of freestone and of neat cement shorter than a cube, showed unmistakably a considerable increase of strength with decrease of length, the area of bed surface remaining the same. A formula is given, designed to express the strengths of such prisms in terms of the strength of a cube having the same bed surface area, and of the average strength per square inch of the material, as obtained from experiments on cubes. It agrees with the results of experiments upon such slabs perhaps as well as could be expected from such material; but its rather complicated form and its limited applicability would seem to forbid it a great measure of practical utility.

In crushed specimens of freestone, the principal fragments, as has been noted in other experiments upon similar materials, generally consisted of one or two irregular pyramids, more or less fully developed, with the bed-faces, or rather the larger portion of the same, as bases.

Eight freestone cubes, with bed-faces carefully smoothed and then coated with a thin film of plaster of Paris, developed generally greater and more uniform strength than similar cubes without the plaster.

Stone blocks, when arranged or built up in courses, have less strength than the individual pieces, but no attempt is made to deduce a law covering such cases.

The absolute resilience of cubes of freestone and of kindred material appears to be approximately proportional to the mass of the cube. The only serious deviation from this appears in certain of the largest (sixteen-inch) cubes of mortar and concrete; and may perhaps be readily explained away in view of the difficulty of securing perfectly similar manipulation and equal and uniform setting in such large specimens.

The resilience of stone pillars, loaded across their entire cross-section, seems to increase as their height increases, while their capacity to resist dead loads decreases.

From earlier experiments it had appeared that specimens of stone, etc. (and especially the stronger ones), were materially weakened by the interposition of wooden cushion-plates between the pressed surfaces of the specimen and the pressure plates of the testing machine, the wood spreading laterally in crushing, and thus exerting a lateral tearing force upon the specimen. This was confirmed by the present experiments upon concrete cubes. "Those crushed directly between the machine heads proved in

every instance stronger than their mates, which were broken between wooden cushions."

Under considerable pressures, the concrete specimens compressed much more rapidly than neat cements or freestone.

Concretes are generally stronger and have greater resilience than the mortars from which they are made; but (which seems contradictory) those mortars and concretes proved strongest and most resilient which were richest in cement. No doubt a more extensive series of tests might show a certain proportion of cement as giving the maximum strength, the strength falling off as this proportion was either increased or diminished.

The *quality* of the cement is of even greater importance than its *quantity*. Mortars and concretes of "National Portland cement are fully three times as strong as the Norton mortars," the specimens being identical in all other respects, although "Norton's cement enjoys a good reputation in the market."

The breaking of a sixteen-inch cube of concrete made from National Portland cement by means of five applications of the maximum load of the machine (800,000 pounds), after it had resisted its first four applications, suggested the importance of extending to such materials as brick, stone, concrete, etc., experiments upon the fatigue of materials, similar in principle to those made upon metals by Wöhler, Spangenberg and Bauschinger.

The six brick piers tested were built up of common hard North River brick with three-eighths inch joints of mortar of one part Newark Company's Rosendale cement and two parts sand. Each pier had a base and cap of North River bluestone, of the same cross section as the pier, and with bed-faces rubbed smooth and plane. The piers were one year nine and a half months old when broken. Their crushing strength varied between 250,000 and 291,000 pounds total, average 266,587 pounds, equivalent to 1,851 pounds per square inch, or 119 gross tons per square foot. This is rather high as compared with the figures generally published for such columns, which, however, are probably based mostly upon work of less age.

The importance of a wider knowledge as to the resilience or blow-resisting qualities of building stones, mortars, masonry, etc., is pointed out. While the present work undoubtedly constitutes, as the author very modestly believes, "a contribution of some value" in this respect, it must yet be regarded as scarcely more than a first step; for with the exception of one or two broad generalizations noted above, its data are chiefly of value in connection with the very few materials experimented with. T.

THE FUNDAMENTAL PRINCIPLES OF CHEMISTRY. By Robert Galloway. London: Longmans, Green & Co., 1888. (J. B. Lippincott Company, Philadelphia. Price, $1.75.)

The title of this work is hardly a correct index of its contents. Of the fifteen chapters into which the book is divided seven treat entirely of the physical properties of matter, the remaining eight being devoted to the principles of chemistry. As there are but about 350 pages, it follows that the latter half—that on chemistry—must necessarily be very condensed and

incomplete. Even this latter half, however, is not satisfactory, for while it is true that the author's idea is to give a description of the principles of the science rather than a list of the *properties* of the different elements, it is difficult to see why the latter should appear at all. And this is all the more true, when we remember how little space there is for the more important theoretical portion—that relating to the "Fundamental Principles." The logical result of this treatment of the subject is that when he comes to the properties of the elements, he may almost be said to give a description in which nothing is described. For example:

Boracic Anhydride.—This compound is prepared by heating the acid to redness; it is a colorless, transparent, vitreous solid.

The value of such a statement, to the student, is simply *nil*, especially when not a solitary word is given of further description.

But the most extraordinary part of the book is the introduction of such a large quantity of matter on physics, in a work which treats of chemistry. Seven pages are given to the description of the air pump; eight to the thermometer. "Capillary Action," makes up the bulk of Chapter VII, "Specific Gravity," the entirety of Chapter V. In some struggling provincial college, where one professor has to teach all the sciences, this jumbling of one with the other might be accepted as the shortest way of covering the greatest space. But how Prof. Galloway could select such a plan as the basis of a new treatise on chemistry, is, indeed, a puzzle. He states in the preface that he is confident that the plan of the book is "more in harmony with the laws of thought than the chemical text-books that are in use in schools, and for teaching junior students generally." But when we remember how many excellent treatises there are on physics and on chemistry, for either the lecture or the laboratory, we are much afraid that the author's confidence, as above expressed, is misplaced. H. P., Jr.

THE CHRONICLE FIRE TABLES FOR 1888. A Record of the Fire Losses in the United States by States, Risks and Causes during 1887, with Exhibits of the monthly, annual and aggregate Fire Losses in the United States during Thirteen Years (1875–1887) and much other valuable information for Fire Underwriters. New York, 1888. Published by the Chronicle Company, Limited. Price, $5.

This invaluable compilation of fire statistics has now reached the fifth volume, having been much enlarged in 1885, and has become indispensable to fire insurance offices and insurance brokers. To many other parties it is advantageous, especially the statistician, historian and political economist. The fires and resulting property losses and insurance losses, are tabulated and grouped by States and Territories, giving clearness and facility of reference. The general student also will find a great mass of valuable information condensed in this volume. There are five diagrams, showing comparative fire losses in the United States during 1887, from known causes; movement of the fire loss for thirteen years; relation of fires to failures; monthly curves of incendiary fires for five years; dwelling-house fires by principal causes, etc.

There are four charts showing geographical distribution of incendiarism

in the United States during 1884, '85, '86 and '87. A large colored frontispiece depicts, in proportionate size of space and amounts in dollars, the fire losses from exposure, incendiarism, defective flues, spontaneous combustion, lightning, explosions, sparks, friction of machinery, matches, engines and boilers, forest and prairie fires, locomotive sparks and sixteen minor causes. These and the detailed tables, show the losses from *known* causes, including exposure, were $53,471,020 in 1887, while the grand total of fire losses for the year was $119,209,380. Finally, at page 125, is a colored diagram with the comparative number of dwelling-house fires in the United States, in 1887, by thirty-six principal causes delineated in relative size, from greatest to least; the proportions and data based on an examination of 32,801 fires in dwellings and tenements.

No other record like this volume is published, the nearest approximation being one annual State fire table and the fire patrol reports of our principal cities. The Chronicle Fire Tables can properly be called one of the most valuable statistical annuals ever attempted in any country; and its value increases with every year of its publication. N.

THE HISTORY OF INSURANCE IN PHILADELPHIA FOR TWO CENTURIES, 1683–1882. By J. A. Fowler. Philadelphia: Review Publishing and Printing Company, 1888. Royal 8vo. 910 pages. Price, $10.

This work, just issued from the press of the Review Publishing and Printing Company, is remarkable and elaborate. Its merits and scope are so great, that it is difficult to know where to commence their enumeration or where to end. In an introduction, the most ancient forms of insurance are given, illustrated by the text and translation of an Italian marine insurance policy of 1385, and a Latin life policy of 1427. These are certainly earlier than any policies as yet published in the United States. The introduction also shows how the insurance idea gradually developed into an important business.

Coming to the years when Pennsylvania and Philadelphia were founded, the author treats largely of the personal Philadelphia and English marine underwriters, showing also, how deferred and survivorship annuities were computed in Boston in 1732, and term fire risks first taken on buildings in Philadelphia by the company, called the "Contributionship," instituted in 1752. Then follow from 1759 to 1825: Life Insurance as Deferred Annuities, 1752–1800; Lottery Ticket Insurance, 1761–1771; Personal Philadelphia Marine Underwriters, 1776–1815; Associated Marine Underwriting, 1792–1803; Corporate Marine Insurance, 1794–1882; Ransom Insurance, 1794–1803; Fire Insurance Upon Personal Property, 1794–1882; Perpetual Fire Insurance on Buildings; General Life Annuities, 1813–1882; Term Contingency and Endowment Life Insurance, 1813–1882; also, Inland Navigation Risks.

The following, besides numerous collateral subjects, are then taken up *seriatim*, each accompanied by data, and most of them by illustrative examples and judicial decisions, to such extent, that the amount of information

furnished is almost bewildering, viz: Health Insurance, 1848–1857; Deposit Life Insurance, 1850–1851; Live Stock Insurance, 1850; Slave Insurance by Philadelphia Companies in Southern States, 1852–1861; The Era of Fraud, 1850–1875; Storm Insurance, 1857; Accident Insurance, 1864–1882; Rent and Leasehold Insurance, 1865–1882; Plate Glass Insurance, 1867–1882; Steam-Boiler Inspection and Insurance, 1868–1882; Industrial Life Insurance, 1879–1882; Fidelity Insurance, 1881–1882.

In the extensive and elaborate researches to obtain data of companies and references to them and their business, in the period 1801–1882, there has been brought to light an amount of information which surprised the historian, and must naturally give more astonishment to his readers. With consummate skill all these facts and figures have been sifted, adapted and interwoven into history, while the various kinds of insurance originating in Philadelphia are fully described, in the rise, flourishing and decay of companies, whose names, date of institution, business and data therewith connected are furnished. There are also many examples given to prove doctrines and formulæ; and a number of reproductions of important policies and other instruments of insurance occur. There must have been an enormous amount of labor and much expense in the collection of all this information, especially the older data; and some of it has evidently been obtained from obsolete and almost unknown sources.

The work is divided into:

PART I.—Marine insurance, marine-fire insurance, fire-marine insurance and insurance in general—where the *main* subjects elaborated (besides many others) number over fifty.

PART II.—Fire Insurance, ditto, eighty *main* subjects.

PART III.—Life Insurance, ditto, seventy-five *main* subjects.

PART IV.—Miscellaneous Insurances, ditto, forty *main* subjects.

The particulars, exemplifications, proofs and data of all these (besides numerous other subjects not here enumerated), though concisely given, make up a vast mass of information, such as rarely has been condensed by one writer into a single large volume. This history is followed by an analytical and topical index, in four parts, corresponding with those above mentioned, comprising nearly 2,800 titles and 4,400 page references.

A conspicuous feature of this exhaustive work is the great attention given to the manufacturing risks of Philadelphia in their inception, progress and development, together with their technological relations to insurance. This story of growth, from small to vast proportions, accompanied by very varying and sometimes wholly disproportionate insurance premiums, is a story such as was never before written of any city or of any country. Philadelphia being the greatest manufacturing city of the United States (probably, indeed, of the world), and as the development of its manufactures, besides aiding fire insurance, contributed to the exportations of the city and increased marine insurance (also indirectly influencing life and miscellaneous insurance), there seems especial fitness in the minute attention paid to this important part of the insurance and manufacturing development of the city.

The technical exactness with which each relation of such risks is traced to its source, its development followed and illustrative calculations and tables made, based on such facts, shows the extraordinary technical and analytical ability of Dr. Fowler as an insurance expert, and as historian of a subject so difficult, even to superior writers in this specialty. As the formation of this history occupied all the time its author could spare from his editorial duties for nearly five years, so it will require the remaining lifetime of the average insurance man to master its contents. Such fact, however, need not prove alarming, for this volume is destined to be one of the standard works of the world, referred to in all time; by which we mean that it will be found needful to all persons and professions having relations with insurance; and the political and social economist will find it indispensable to his studies.

To the general reader, perhaps, the most special interest of this book will be its character as a history of the city of Philadelphia. It may properly be regarded as the most successful attempt ever made to present the record and details of the economic development of a locality. In such respect this production may be pronounced wonderful, and as a history of the city of Philadelphia merely, is the greatest that has yet been written. It is doubtful whether any other metropolis can present an equally explicit and instructive narrative.

In relation to this, his masterpiece, Dr. Fowler, might well predict, as Horace did of his own productions:

> Exegi monumentum ære perennius,
> Regalisque situ pyramidium altius;
> Quod non imber edax, non Aquilo impotens
> Possit diruere, aut innumerabilis
> Annorum series, et fuga temporum!

LEITFADEN FÜR DEN UNTERRICHT IM SCHIFFBAU. Von A. van Hüllen, Kiel und Leipzig: Lipsius & Tischer.

This work, the author of which is chief engineer in the German Navy and instructor at the Naval Academy at Kiel, Germany, is principally intended for use at such institutions, hence more attention is paid to war vessels than to those for mercantile purposes, and considerable space is devoted to construction of wooden vessels, which, although on the decline for merchant service, are still of some importance for naval purposes.

The chief merit of the work is the minuteness with which all operations in ship construction are described, from the first plan, the laying down on the mold loft, the building ways, the details of the structure, etc., until the final completion, launching and equipment,

Comparing wood and iron ships, their respective elements of strength, under different conditions, are very clearly stated. The chapters devoted to the conservations of vessels by painting, cementing, etc., are also interesting, while those on water-tight bulkheads and drainage arrangements are fully up to the latest improvements in modern war vessels.

The chapter on armor is profusely illustrated with the latest varieties of armored vessels, and details of armor construction. Chapters on rudder and steering apparatus, on spars and boats conclude the practical part of the

work, the remainder being devoted to hydrostatics of ship construction, tonnage measurement, stability, the action of sails, resistance of vessels and other scientific matters relating to naval architecture. This part, while treated with great thoroughness, is yet simpler than most works on this subject, being almost entirely free from higher mathematics, a consideration of importance to those, who, after years of practice in the engineering profession, have become somewhat rusty in the integral and differential calculus. J. H.

THE ASHCROFT MANUFACTURING COMPANY'S IMPROVED TABOR INDICATOR.

In this improved instrument, the arrangement of the parallel motion mechanism is reversed, by which means a range of motion of the pencil of 3·25 inches is obtained. The curved slot by which the pencil is made to move in a straight line is transferred from the piston rod to a stationary guide, firmly secured to the cover of the cylinder. In the new instrument the roller is the moving part, whereas in the old instrument it was stationary. By the above changes the parallel motion multiplies the piston movement five times.

The treatise accompanying the instrument is designed for reference and contains instructions for purchasers and others interested in the subject.

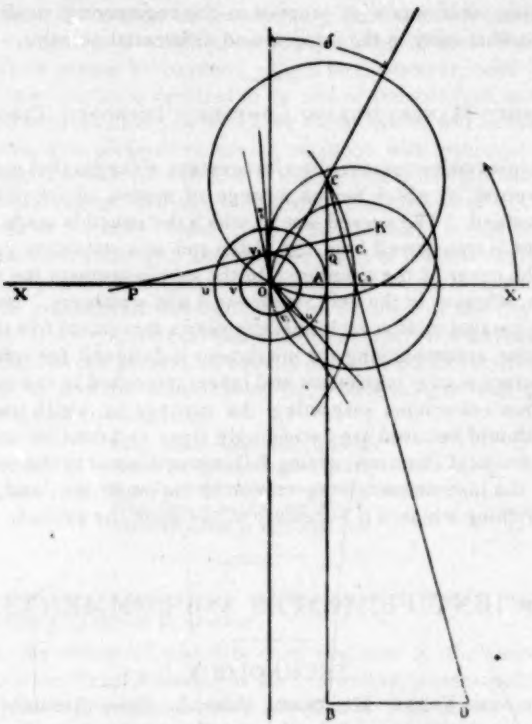
Mr. Barrus' directions respecting the manner in which the improved instrument should be used are exceedingly clear and concise, and are of a thoroughly practical character, giving full instructions as to the best methods of securing the instrument, giving motion to the paper, etc., and, in fact, including everything which it is necessary to say upon the subject. LE VAN.

SCIENTIFIC NOTES AND COMMENTS.

TECHNOLOGY.

THE ZEUNER VALVE DIAGRAM. John L. Gow, Assistant Engineer, U. S. N.—In the application of the Zeuner diagram to valves fitted with link motions giving unequal leads for different positions of the link, the use of the graphical method of solution becomes more complicated from the fact that the centre of the valve circle moves in the arc of a parabola as the link is raised or lowered. That is, in the figure if C, C_1, C_2, are the centres of valve circles corresponding to three different positions of a Stephenson's link, then the curve $C\,C_1\,C_2$ is a parabola. A circle whose centre is on the line $X\,X_1$ and passing through the points C and C_2, will be found to practically coincide with the part of the parabola used in the diagram. To draw this circle the following method is given. In the figure suppose C to be the centre of the valve circle when the link is in full throw. From C draw the line $C\,B$ at right angles to $O\,X_1$, and make $C\,B$ equal to the length of the eccentric rod. At B draw a line parallel to $O\,X_1$, and lay off a distance $B\,D$ equal to the half length of the link, to the right if the rods are open and to the left if crossed. Join C and D and the point C_2 where $C\,D$ crosses $O\,X_1$, is a second point in the

circle. Bisect $C\,C_2$ by the perpendicular $P\,K$ and the point P where this line cuts $O\,X$ is the centre of the circle and $P\,C_2$ is the radius. Suppose it is desired to determine the distribution of the steam if the link is one-third the way down. Mark the point Q so that $A\,Q = \frac{1}{3}\,A\,C$. Draw $Q\,C_1$ parallel to



$O\,X_1$, and take the point C_1 where it cuts the circle as the centre of the valve circle and $C_1\,O$ as a radius. If $O\,U$ is the steam lap and $O\,V$ the exhaust lap, the steam port opens when the crank gets to $O'\,U_1$, and closes at $O\,U_2$ and the exhaust port opens at $O\,V_1$, and closes at $O\,V_2$.

The travel of the valve as given by Zeuner, third edition, p. 63, for Stephenson's link with open rods, omitting the last term is

$$r\left(\sin\delta + \frac{c^2 - u^2}{c\,l}\cos\delta\right)\cos\omega + \frac{u\,r}{c}\cos\delta\sin\omega$$

in which r is the half travel of the valve, δ is the angle of advance, c the half length of the link, u the distance the link has moved from its central point, l the length of the eccentric rod, and ω is the amount the crank has moved from the dead point. For different positions of the link, or different values

of u, the centre of the valve circle is at the points whose co-ordinates are

$$\frac{r}{2}\left(\sin \delta + \frac{c^2 - u^2}{c\,l} \cos \delta \right)$$

and

$$\frac{u\,r}{2\,c} \cos \delta$$

If the link is in full throw then $u = c$ and the co-ordinates become

$$O\,A = \frac{r}{2} \sin \delta$$

and

$$A\,C = \frac{r}{2} \cos \delta$$

The point C is usually determined graphically in using the diagram. If $u = o$ or the link is in mid-position then the co-ordinates become

$$\frac{r}{2}\left(\sin \delta + \frac{c}{l} \cos \delta \right) = O\,C_2 \text{ and } o$$

To prove that our construction makes

$$O\,C_2 = \frac{r}{2}\left(\sin \delta + \frac{c}{l} \cos \delta \right)$$

we have

$$O\,C_2 = O\,A + A\,C_2$$

But

$$O\,A = \frac{r}{2} \sin \delta$$

and from the figure

$$\frac{A\,C_2}{A\,C} = \frac{c}{l}$$

or

$$A\,C_2 = A\,C \times \frac{c}{l}$$

But

$$A\,C = \frac{r}{2} \cos \delta \quad \therefore \quad A\,C_2 = \frac{r}{2} \cdot \frac{c}{l} \cos \delta$$

and

$$O\,C_2 = \frac{r}{2}\left(\sin \delta + \frac{c}{l} \cos \delta \right)$$

as before.

As we have never seen an easy method by which the influence of the link could be graphically laid down, it is believed that the method above given will allow the entire distribution of steam to be investigated without any other work than can be done on a drawing board. H. W. S.

TO DETERMINE THE SIZES OF CYLINDERS FOR SUCCESSIVE EXPANSION ENGINES. John L. Gow, Assistant Engineer, U. S. N.—Assume that *Fig. 1* represents the combined theoretical cards for an engine having n cylinders. Let V_1 be the volume of the high pressure cylinder to the point of cut-off;

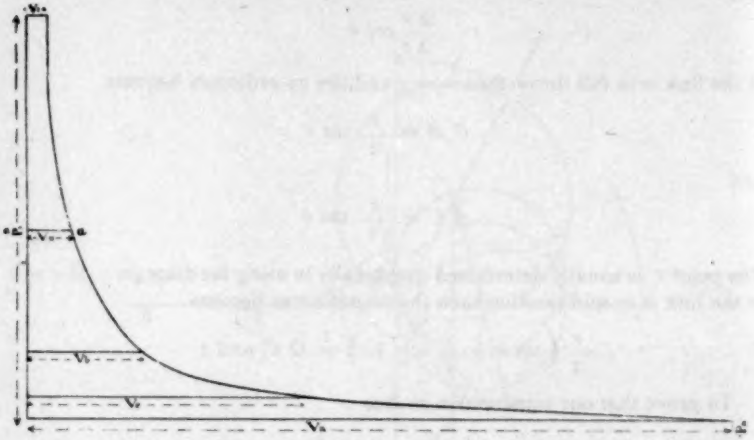


FIG. 1.

V_a, the total volume of the first cylinder; V_b, that of the second; . . . V_n, that of the last or low pressure cylinder. Let P_1 be the initial absolute pressure and P_n the final back pressure. Assume that the law of the expansion is $PV =$ a constant, and that the expansion in the nth cylinder is carried on to the back pressure line. If r is the total number of expansions then

$$r = \frac{P_1}{P_n}.$$

The area of the entire card will then be

$$A = P_1 V_1 (1 + \log_e r) - P_n V_n = P_1 V_1 \log_e r. \quad . \quad . \quad . \quad (1)$$

Below the line $a\ a$ the area of the card is

$$\frac{n-1}{n} A = P_a V_a \left(1 + \log_e \left\{\frac{V_n}{V_a}\right\}\right) - P_n V_n = P_a V_a \log \left\{\frac{V_n}{V_a}\right\}$$

and below any line as the dth the area is

$$\frac{n-d}{n} A = P_d V_d \left(1 + \log_e \left\{\frac{V_n}{V_d}\right\}\right) - P_n V_n = P_d V_d \log_e \left\{\frac{V_n}{V_d}\right\}$$

or

$$A = \frac{n}{n-d} P_d V_d \log_e \left\{\frac{V_n}{V_d}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and combining (1) and (2) we have

$$\frac{n}{n-d} P_d V_d \log_e \left\{\frac{V_n}{V_d}\right\} = P_1 V_1 \log_e r$$

or, as $P_1 V_1 = P_4 V_4$,

$$\frac{n}{n-d} \log \left\{ \frac{V_n}{V_4} \right\} = \log_e r .$$

$$r = \left\{ \frac{V_n}{V_4} \right\}^{\frac{n}{n-d}}$$

or

$$V_4 = \frac{V_n}{r^{\frac{n-d}{n}}} \quad \ldots\ldots\ldots\ldots \quad (3)$$

To apply this formula to a triple expansion engine $n = 3$, and making $d = 1$ and 2, we have for the horse-power cylinder

$$V_1 = \frac{V_3}{r^{\frac{2}{3}}}$$

and for the intermediate cylinder

$$V_2 = \frac{V_3}{r^{\frac{1}{3}}} .$$

For a quadruple expansion engine the cylinders would be

$$\frac{V_4}{r^{\frac{3}{4}}}, \frac{V_4}{r^{\frac{1}{2}}}, \frac{V_4}{r^{\frac{1}{4}}}, \text{ and } V_4.$$

Equation (3) can be put into a more convenient form by putting

$$\frac{\pi D^2 L}{4} \text{ for } V$$

D being the diameter of the cylinder and L the stroke. The formula then becomes

$$D_4 = \frac{D_n}{r^{\frac{n-d}{2n}}}$$

or the diameter of any cylinder can be formed directly from the ratio of expansion and the diameter of the low pressure cylinder. An application of this formula to many of the triple and quadruple expansion engines lately built will show that the dimensions obtained from the formulæ agree very well with recent practice.

The following are some of the latest quadruple engines built:

					Calculated.	
	H. P.	*L. P.*	*Second.*	*Third.*	*Second.*	*Third.*
County of York,	20	57	28½	—40	28·34	40.2
Grace Darling,	10	28	14	20	14·09	19·86
Myrth,	12	34	17	24	16·98	24·02
City of Venice,	30	70	40	52	39·78	52·77
Buenos Ayres,	32	90	46½	64½	45·50	64·80
Suez,	22	62	30	43	31·11	43·89

H. W. S.

CHEMISTRY.

ON THE PREPARATION OF PURE HYDROGEN IODIDE.—Lothar Meyer (*Berl. Ber.*, **20**, 3,381). The author finds that the phosphonium compounds usually present in hydriodic acid are owing to the use of an excess of phosphorus in the preparation. The formation of such compounds may be avoided by operating in the following manner: 100 grammes of iodine are introduced into a tubulated retort, whose neck is inclined upwards, and moistened with ten grammes of water. To the tubulure of the retort is adapted a funnel, the extremity of whose opening is closed by a glass rod, ground in. In the funnel is placed a mixture of five grammes of amorphous phosphorus and ten grammes of water, and when the apparatus is ready *a single drop* of this mixture is allowed to fall into the retort. If more than a single drop be added the reaction becomes exceedingly violent and terminates in an explosion. When the reaction of the first drop is apparently complete, another drop is added, and in a short time the addition may be made more rapidly; a quarter of an hour is required for the quantities named. No heat is necessary for the evolution of the gas, but at the close of the operation a gentle heat may be applied, and the iodine that has been carried over by the hydrogen iodide and deposited in the neck of the retort, is washed back by the condensed vapor. If it is desired to obtain all the acid as the product of one operation, the neck of the retort is now inclined downwards, and the liquid distilled; any unaltered phosphorus present should first be removed from the liquid by filtration. The residue is syrupy, colorless phosphoric acid. W. H. G.

UTILIZATION OF PETROLEUM "SLUDGE ACID."—W. P. Thompson (*Journal of the Soc. Chem. Industry*, 1888, p. 353) gives some account of Rave's process for obtaining valuable products from this waste material. The tarry acid is kneaded with iron borings or filings, copper or zinc or other metallic cuttings, the material preferred being iron cuttings or borings. After more or less prolonged contact, depending upon the nature of the metal and its degree of fineness, the sulphuric acid will be found to have combined with the metallic base. The mass is now introduced into heated receptacles and boiling water is added. The metallic sulphate dissolves and separates from the black mass and the latter melts and rises to the surface. It is withdrawn from the receptacle, and is found to have all the mechanical properties of the best purified soft bitumen. It is well washed with hot water to remove all traces of salts and the wash waters used to dissolve out fresh quantities of salts in a succeeding operation. Any uncombined metal falls to the bottom. The watery solution containing the metallic sulphate and other salts is drawn off into crystallizing reservoirs.

The black mass, or bitumen, being too soft for many purposes, is placed in a still and heated until it assumes the required degree of hardness. The hydrocarbons given off in this operation are collected and used as naphtha. The resulting bitumen is very pure and can be used for almost all purposes for which the purest native bitumens are used, while at the same time it is so elastic and malleable as to strongly resemble india-rubber; hence it is largely sold by the Société Oleo-graisse, who work the Rave process under the name

of "mineral caoutchouc-bitumen." One ton of acid tar produces about ten hundredweight of this purified bitumen. If the distillation of the soft bitumen be carried farther, a material soluble in naphtha but nearly as hard and tough as ebonite is obtained. This is an extremely good non-conductor of electricity, is unacted upon by acids or alkalies, and is therefore adapted for making galvanic batteries, for coating acid tanks, conducting wires and cables, for insulation plates and the like. It can be made of all degrees of hardness and moulded by heat, either pure or admixed with fibrous and strengthening materials.

If the mineral caoutchouc-bitumen be mixed with about forty per cent. of sawdust and a little lime, heated in an iron vessel and pressed into moulds, it makes an admirable fuel, burning well in a fireplace without melting and with little ash.

The "mineral caoutchouc-bitumen" dissolves readily in petroleum, naphtha and other light hydrocarbons, and forms an excellent tough, black varnish. This varnish is water-proof and adheres very tightly to metal, not chipping or scratching off so easily as Brunswick black or Japan varnish. The bitumen also forms compounds with rosin, wax, pitch and other like materials, with qualities intermediate between those of their constituents.

To sum up, at the expense of the requisite quantity of iron cuttings or oxide, the entire sulphuric acid in the material is obtained as green vitriol. One-half the weight of the original acid tar is utilized as soft bitumen, or this is still further differentiated by distillation and this fifty per cent. is converted into seventeen per cent. light naphtha and burning oils; eight per cent. heavy lubricating oils, and twenty-five per cent. metallic carbon.

S. P. .

Recovery of Sulphur from Alkali Waste by Means of Lime-Kiln Gases.—What seems to be a fundamental improvement of the well-known Leblanc Soda process has just been announced by Mr. Alexander M. Chance (*Jour. Soc. Chem. Indust.*, 1888, p. 162). The process claims to recover, either in the form of brimstone or as sulphuric acid, ninety-five per cent. of the sulphur previously wasted in the calcium sulphide of the Leblanc method, and as the quantity of pyrites used exclusively for making soda by the Leblanc process, the sulphur of which is now thrown away, is estimated at about 300,000 tons a year, it will be seen that the success of the new process means almost a commercial revolution. The process is based upon certain patents issued in 1882 to C. F. Claus for recovering sulphur from the sulphuretted hydrogen of coal gas. Carbonic acid diluted with nitrogen, as given off from the lime-kiln, is used to decompose the calcium sulphide or alkali waste, and liberate hydrogen sulphide in a regular stream. This gas, mixed with a proper amount of air, is passed over heated oxide of iron or other contact substances, whereby it is burned according to the reaction $2\,H_2S + O_2 = 2\,H_2O + S_2$. The oxide of iron is maintained by the heat of the reaction at a dull red heat and undergoes no change, while free sulphur accompanied by vapor of water passes off. The free sulphur is obtained in the fused or sublimed form according to the temperature of the kiln and of the depositing

chambers. Or, by burning the sulphuretted hydrogen as liberated, the whole of the sulphur may be utilized in the sulphuric acid manufacture, the heat of the burning gas being sufficient to work the Glover tower. Of great importance is the ingenious method of getting rid of a considerable quantity of the diluting nitrogen before attempting to burn the sulphuretted hydrogen gas. This is done by passing the H_2S and nitrogen liberated by the lime-kiln gases from one portion of waste into another vessel with a further quantity of waste which absorbs the H_2S to form $Ca(HS)_2$, leaving the nitrogen go on unabsorbed. The carbon dioxide attacking this liberates a double quantity of H_2S according to the reaction, $CO_2 + Ca(HS)_2 + H_2O = CaCO_3 + 2H_2S$. The gas is now sufficiently rich in H_2S to burn as before represented. The sulphuric acid produced by this process is extremely pure, being quite free from arsenic, contains a mere trace of iron and is almost colorless. Very interesting statements as to the cost of the process and the great saving effected by its use are given and illustrations of the necessary apparatus.

S. P. S.

THE SUPPOSED IDENTITY OF RUTIN AND QUERCITRIN.—E. Schunk. (*Proc. Chem. Soc.*, **47.**) 1887–88. The author employed a sample of quercitrin, made by himself from quercitron bark, and it was found to have the composition and properties assigned it by Liebermann and Hamburger. The rutin was prepared from buckwheat leaves.

A comparative examination of the two substances led to the conclusion that they differ essentially as regards composition, but that they are still extremely similar.

Rutin yields with acids the same products of decomposition as quercitrin, viz: quercetin and iso-dulcite, but not in the same relative proportion; it gives less quercetin and more iso-dulcite.

The analyses of rutin agree with the formula $C_{42}H_{50}O_{25}$, that of quercitrin being $C_{36}H_{38}O_{20}$. The process of decomposition by acids would be represented by the equation:

$$C_{42}H_{50}O_{25} + 4H_2O = C_{24}H_{16}O_{11} + 3C_6H_{14}O_6.$$

Hence it would appear that rutin is derived from one molecule of quercetin and three molecules of iso-dulcite, and quercitrin from only two molecules of the latter and one of the former.

H. T.

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